The Canadian Entomologist

Vol. LXXXVI Ottawa, Canada, January 1954 No. 1

Distribution and Life History of the Lodgepole Needle Miner (*Recurvaria* sp.)[1] (Lepidoptera: Gelechiidae) in Canadian Rocky Mountain Parks[2]

By R. W. STARK[3]

Introduction

General. The life history of the lodgepole needle miner in Yosemite National Park, California, has been described (24). The Canadian outbreak was discovered in 1942 but intensive investigations were not commenced until 1948. Many differences have been noted between the Canadian and Californian life histories since the discovery of the outbreak.

It is the purpose of this paper to bring together all information collected by the author and staff of the Laboratory of Forest Zoology at Calgary, Alberta, concerning the life history of the lodgepole needle miner in the Canadian Rocky Mountains.

Historical Review. The outbreak was first noticed in June, 1942, on an area of approximately 50 square miles in Banff National Park where it joins Kootenay National Park at Vermilion Pass. No change was reported in 1943 but in 1944 the infestation spread into Yoho and Kootenay national parks for short distances. In 1945 the area of the outbreak was estimated to be 200 square miles (1, 9, 10). G. R. Hopping, then Officer-in-Charge of the Vernon laboratory, had been in this area for brief periods since 1942 and described the general life history, based largely on Patterson's description supplemented by field checks and observations of abundance and damage (11, 12). By 1946 the area of infestation had increased to 300 square miles and it was noted that, although prior to 1946 the miner was confined to altitude levels from 5,000 to 6,500 feet, the outbreak had been extended into the valley bottoms, approximately 4,600 feet in this region (1, 13). In 1947 D. K. Campbell of the Vernon laboratory was assigned to this project for a short time. He attempted to determine the population present and experimented with chemical controls. His results were inconclusive (4). No change was reported in the extent of the outbreak (1).

The Laboratory of Forest Zoology at Calgary was established in May, 1948. One of its principal projects was the lodgepole needle miner and the author was assigned as project leader. The objectives were to determine the life history, precise sampling methods, and possible controls (14). A second outbreak in Jasper National Park was reported (19, 27).

In 1949, K. Graham of the University of British Columbia was assigned to the project with the author. There was no change in distribution or abundance in 1949 in the main outbreak area, but needle miners were found in small numbers on the eastern slopes of the Rocky Mountains bordering Banff National Park (6, 20).

In 1949-50 there was a heavy winter kill of needle-miner larvae. The outbreak in the Bow Valley of Banff Park was reduced approximately to the area of 1942, the larvae below the 5,000-foot level suffering over 90 percent mortality.

[1]Previous publications have called this insect, found in Rocky Mountain National Parks, *Recurvaria milleri* Busck, but there now exists some doubt as to its being the same species as described by Busck (3) from Yosemite National Park. The genus is being reviewed.

[2]Contribution No. 96, Division of Forest Biology, Science Service, Department of Agriculture, Ottawa, Canada.

[3]Agricultural Research Officer, Laboratory of Forest Zoology, Calgary, Alberta.

However, the populations in Yoho, Jasper, Kootenay, and some parts of Banff Park were not subjected to the same winter conditions and the mortality was low (16, 17, 21). There was no increase in the outbreak area of 1951 (22).

In 1952 a precise sampling method was perfected (35) and the distribution was determined using the sequential sampling technique (34). Valuable ecological studies were made on the effects of solar radiation on the temperatures within the needle mines (7).

Importance. The Canadian outbreaks are confined to four national parks; Banff, Yoho, Kootenay, and Jasper. The host tree of the needle miner, *Pinus contorta* Douglas var. *latifolia* Engelm., is present in great abundance throughout the outbreak area. These four parks constitute one of the most important tourist and recreational areas in Canada and any threat to their forests is of vital concern. At the present time there appears to be no obstacle, other than climate, that can restrict the spread of the needle miner throughout the lodgepole pine stands of the national parks (15).

In the ten years the outbreak has existed, there has been little mortality even in an area of overmature pine. However, the weakening effect of severe and constant defoliation has reduced the vigour of many trees and these may succumb to secondary insects.

Although a relationship has not been proven, some needle-miner attacks in the United States have been followed by devastating attacks of the mountain pine beetle (24). This danger exists in the Canadian outbreak. As late as 1942, a serious bark-beetle outbreak in Banff National Park was brought under control with great difficulty (11).

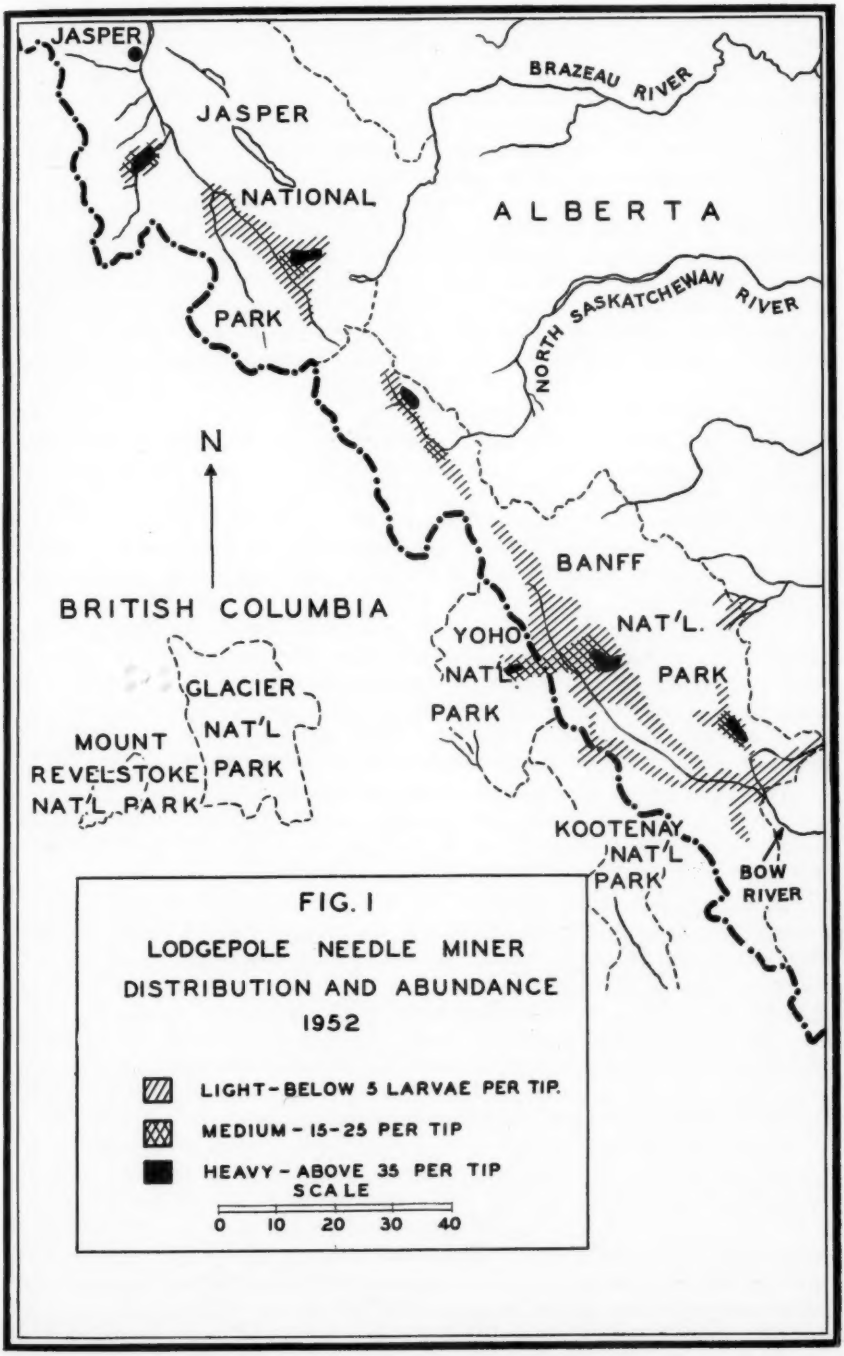
Present Distribution

Fig. 1 shows the distribution and abundance of needle-miner populations as determined prior to moth flight in 1952. The present outbreak covers approximately 350 square miles, as compared with 450 square miles at its peak prior to 1950. In Banff Park there are three extremely heavy populations; one is located in the Cascade Valley, about 16 miles northeast of Banff, the second in the Lake Louise area, and the third in the northern part of the park around Mount Coleman. In Jasper Park there are two centres of extremely heavy populations; Poboktan Creek, 40 miles south of Jasper, and Mount Edith Cavell, nine miles southwest of Jasper.

Those areas indicated as heavy vary in degree; the percentage of needles infested is 50 to 80 percent in Jasper Park, 80 to 90 percent in Banff Park, and approximately 50 percent in Yoho Park. A medium infestation indicates from 25 to 35 percent of needles infested, the light below 15 percent.

Life Cycle

The life cycle of the needle miner covers approximately 24 months, of which 21 are spent in the larval stage. Adults normally appear in even-numbered years i.e. 1950, 1952. Moth emergence begins in the first week in July and is generally completed by the first week of August. During the first part of the emergence period males and females are roughly in the proportions 4 to 1 respectively, by July 25 the proportions are about equal and towards the end of moth flight, females are predominant (28). Copulation begins soon after emergence and eggs are found up to the second week in August. From this time until the early summer of the next even year, only larvae are present in the field. The larvae thus hibernate twice, and it has been demonstrated that hibernation is not obligatory but is caused by low temperatures, usually in October (18, 25). Pupation begins early in June of the next even year and is completed by June 30.


JASPER
JASPER
NATIONAL
PARK
BRAZEAU RIVER
ALBERTA
NORTH SASKATCHEWAN RIVER
N
BRITISH COLUMBIA
BANFF
NAT'L.
PARK
YOHO
NAT'L
PARK
GLACIER
NAT'L
PARK
MOUNT
REVELSTOKE
NAT'L PARK
KOOTENAY
NAT'L
PARK
BOW
RIVER
FIG. 1
LODGEPOLE NEEDLE MINER
DISTRIBUTION AND ABUNDANCE
1952
LIGHT - BELOW 5 LARVAE PER TIP.
MEDIUM - 15-25 PER TIP
HEAVY - ABOVE 35 PER TIP
SCALE
0 10 20 30 40

The Moth

Description.—The needle-miner adult is a small, narrow, grey moth about 6 mm. long with a wing expanse of 12 to 14 mm. When at rest the wings are folded back over the body, extending slightly beyond the tip of the abdomen. The antennae of the male are more hairy than the female, having a ring of dark hairs at the middle and base of each segment, whereas the female has hair only at the base of each segment and these are sparse and not as heavily coloured. The number of antennal segments varies from 30 to 40, the average being about 35. The front of the head is white to silvery-grey, the thorax usually grey. The forewings are extremely variable, from pale- to dark-grey, with apparently "aimless and fugitive" black markings (3). The hind wings are creamy-white, cilia slightly darker. The abdomen is usually silvery-white and in the males there is a large bluish-black spot on the dorsum of the mid-abdominal region. The legs are white annulated with black. The anal cilia of the male extend beyond the tip of the abdomen, whereas in the female these cilia are sparse and extend barely to the end of the abdomen (Fig. 2a).

Behaviour.—Field observations and laboratory experiments indicate a rather complex behaviour of the moths. Their responses to given stimuli are not consistent under all conditions but may be modified by temperature, moisture, wind, age, sex, and possibly mating and other factors. Perhaps the most consistent reaction is to light. This response is generally positive under most temperature conditions but is more evident when the light is restricted and diffuse, such as on overcast days and at twilight.

Generally, the moths are quiescent under the following conditions: when temperatures are less than 43° Fahrenheit, when there are even light winds, or when it is raining. Flight activity is both diurnal and nocturnal, subject to the above stimuli, but the maximum is at temperatures above 50°F. when the light source is diffuse and there is no wind. These periods generally occur in mid-afternoon when the day is bright but overcast, or during twilight.

On bright sunny days with no wind and cloudless skies, flight is common but desultory; the moths are largely quiescent, seeking the shade of inner foliage, shaded sides of tree trunks, and on the ground litter. On cool days the moths seek the exposed portions of the crown and tree trunks.

In observations made, maximum flight activity occurred when the relative humidity was from 50 to 60 percent, but the reduced flight at other humidity levels may have been due to wind or extremes of temperature.

The flight of the moth appears weak and irregular, although it has been observed to fly 50 yards. Most flights, however, are short, from tree to tree or from the crown to the ground or vice versa. Conditions for mating are apparently critical since all attempts to mate moths under artificial conditions failed. Copulation probably takes place on the foliage or on the ground, but copulating pairs have been observed in flight, the female dragging the male.

The moth searches for mined needles in which to oviposit by walking up one side of a needle and down the other, lowering its abdomen at frequent intervals. This procedure continues without pause until an exit or entrance hole is found. If it is an entrance hole it is usually rejected, the moth going almost directly to the exit hole on the other side of the needle. The egg-laying site is explored by probing with the abdomen. If it is suitable the female inserts her ovipositor and remains in that position for several minutes during oviposition. The eggs are laid within 3 mm. above or below the exit hole. Although single eggs are found, they are usually in clusters of from 3 to 16 (25) (Fig. 9). Numerous

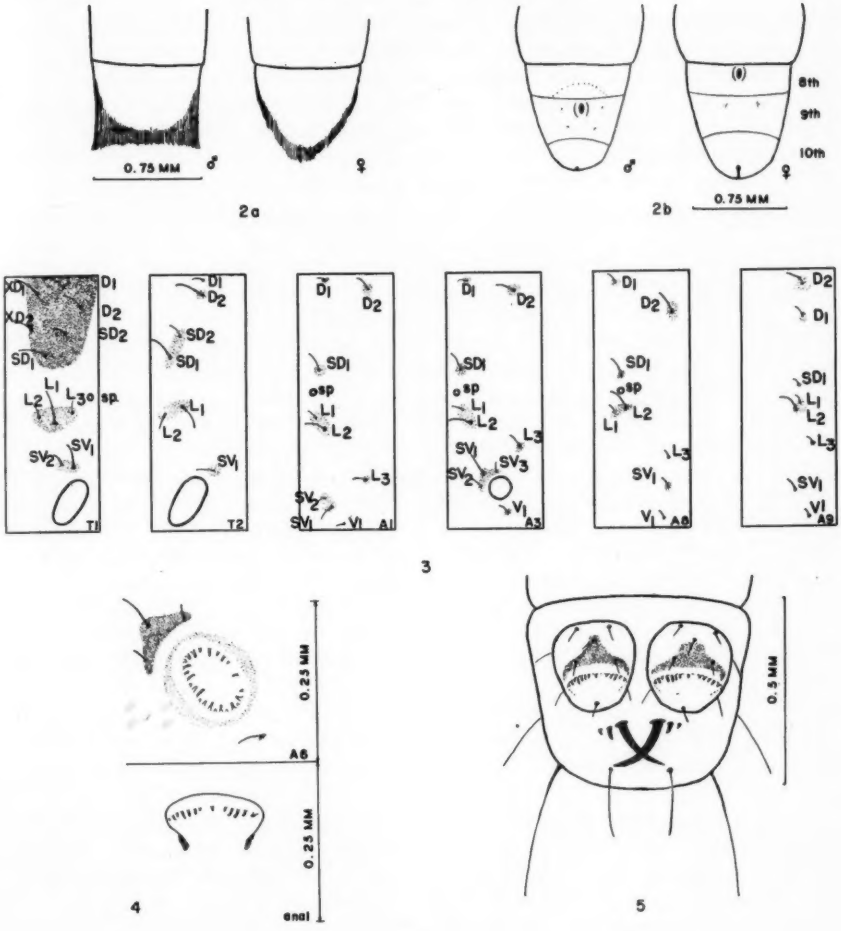


Fig. 2a: terminal segment of moths; fig. 2b: terminal segment of pupae; fig. 3: setal map using Hinton's (1946) nomenclature; fig. 4: abdominal and anal crochets; fig. 5: anal comb.

Figs. 2-5. Details of setal arrangement.

dissections of moths revealed 16 to 30 fully formed eggs in the ovary and four ovarioles containing up to 120 immature eggs.

Although needle mines are preferred, the moths lay in other sites. Secondary choices are: in or around the needle sheaths and, rarely, in the fork of the needles or on the rough, flat, inside surface of the needle. Patterson cites the needle sheath as the preferred location, but in material shipped to this laboratory from California, eggs were found in both sites.

The Egg

Description.—The egg is ovoid and from 0.3 to 0.5 mm. in length, creamy-yellow, with a transparent chorion. The chorion is not definitely sculptured but appears pebbled (Fig. 9).

Incubation period.—Observations of freshly deposited eggs in the field indicate an incubation period of 15 days but considerable variation has occurred in the past three moth flight years. Eleven days is the minimum under favourable laboratory conditions but periods up to 45 days have been observed in the field during extremely unfavourable weather. An egg, with the larva about to emerge, is illustrated in Fig. 10.

The Larva

Description.—Measurement of many head capsules and field and laboratory observations have led to the conclusion that there are five larval instars (33). Table I presents the mean head-capsule widths of the five instars as well as the mean length and width. For the latter two measurements 25 larvae in each stadia were used.

TABLE I

Comparative Sizes of the Five Larval Instars: Head-Capsule Widths, Length of Body, and Body Width. (Measurements in millimetres).

Instar	Mean Head Width		Mean Body Length		Mean Body Width	
	Male	Female	Male	Female	Male	Female
I	.158		1.22		.172	
II	.240		2.44		.343	
III	.364	.362	3.38	2.92	.552	.475
IV	.446	.460	4.90	5.60	.677	.701
V	.537	.532	7.31	6.60	.968	.877

Ecdysis between the first and second, and the second and third instars has been observed in the field, and there is no reason to doubt that the measurements of these instars are reasonably precise. The fourth and fifth instars, however, are not so well defined. There is a great variation in sizes and each of the two instars exhibits bimodality but the modal means are not significantly different. It is interesting to note that Beck reports: "one moult, (not always the first) results in a greater increase in head widths than any of the other instars." His observations were based on insects other than the lodgepole needle miner (2). The above data agree with his observations. In this case it is the change from second to third instar, the other increases being practically at a constant ratio (33).

The colour of the needle-miner larva changes slightly throughout its life. The colour of the first-instar larva is a pale lemon-yellow to light-orange. The prothoracic and anal shields are a pale-brown. The head capsule is light-brown with a conspicuous dark spot in the centre of the ring of ocelli. In the second instar all colours are slightly darker, the body colour pale yellow-brown and the ocellar spot not conspicuous. The body colour of the third instar is a uniform yellow-brown, the prothoracic and anal shields dark-brown, and head capsule dark-brown to black. The gonads in the male become visible on the dorsum as pale, bluish bodies, between the fourth and sixth abdominal segments. The last two instars are similar, except that in the latter the body colour darkens slightly and the male gonads are darker and more pronounced.

No difference was found in the setal patterns of the last three instars and the value of comparing that of early instars is questionable for field work. Therefore, only the setal pattern of a mature larva is described, using Hinton's classification (8) (Fig. 3). The numbers and distribution of crochets on the abdominal and anal prolegs are shown (Fig. 4) as well as the anal comb (Fig. 5). Crochets of the abdominal prolegs number approximately 26; these are biordinal and arranged in a complete circle. On the anal proleg the crochets number approximately 14 and are arranged in a transverse row. The anal comb consists of two long, curved spines flanked on each side by two smaller spines.

Behaviour.—To facilitate recognition of the larval stages in the field, the normal behaviour of the larva is treated by instar. Variation in behaviour caused by external influences will be discussed in a later section.

First instar.—First-instar larvae are found in the field from August to October in the even-numbered years, i.e. 1950, 1952, following moth flight. The larva begins to mine a needle soon after emerging from the egg, the majority preferring the needles of the previous year's growth. An odd fact is, that unless the population is extremely heavy, only one of the two needles in the bundle is mined. It is not known by what mechanism the larva avoids a bundle with one needle already mined. Entrance into the first needle is invariably in the distal quarter and almost invariably from the outside of the needle i.e. the curved surface, usually taking the better part of a day. Generally, the larva seals the entrance hole with silk. The mines are thread-like and generally confined to the distal quarter of the needle. Sometimes before reaching the tip they reverse direction but the mines seldom extend more than a few millimetres below the entrance hole. Moulting takes place before hibernation and the exuvia can be found in the needle mine.

Second instar.—Second-instar larvae are found from early October of the moth flight year to early June of the next year. The larva resumes mining the first needle late in April or in the first week of May. The mines are usually half the width of the needle by moulting time. Not infrequently the larvae of this instar transfer to fresh needles in the spring, leaving partially mined, but still green needles. The majority, however, finish mining and moult before transferring to the second needle, usually in July. Frequently, the larva chews an exit hole close to, and on the convex side of the tip of the needle. The larva keeps the mine clear of frass by pushing it out of the exit hole.

Third instar.—Third-instar larvae are found from early June to September of the odd-numbered year i.e., 1949, 1951. As mentioned above, it is mainly this instar that is involved in the mass transfer to the second needles. The time spent in transferring is approximately nine hours. Generally, the needles of the previous year's growth are preferred, although needles of almost any age, with the exception of the current year's, may be attacked. Unlike the first instar, entrance is usually effected from the flat surface but is still in the distal quarter of the needle, and the larva excavates the tip before mining downward. By late October, half to three-quarters of the needle is completely mined and the characteristic yellow of the foliage is noticeable. This larva also keeps the mine clear of frass by pushing it out of the exit hole. Moulting generally occurs before hibernation but some third-instar larvae may overwinter.

Fourth instar.—Fourth-instar larvae are found from October of the odd-numbered year to the middle of May in the moth flight year. Feeding is resumed late in April or the first week in May. The larva feeds voraciously, and by the third week in May it has usually completely mined the second needle in which it overwintered. Ecdysis usually occurs before the transfer to the third needle in

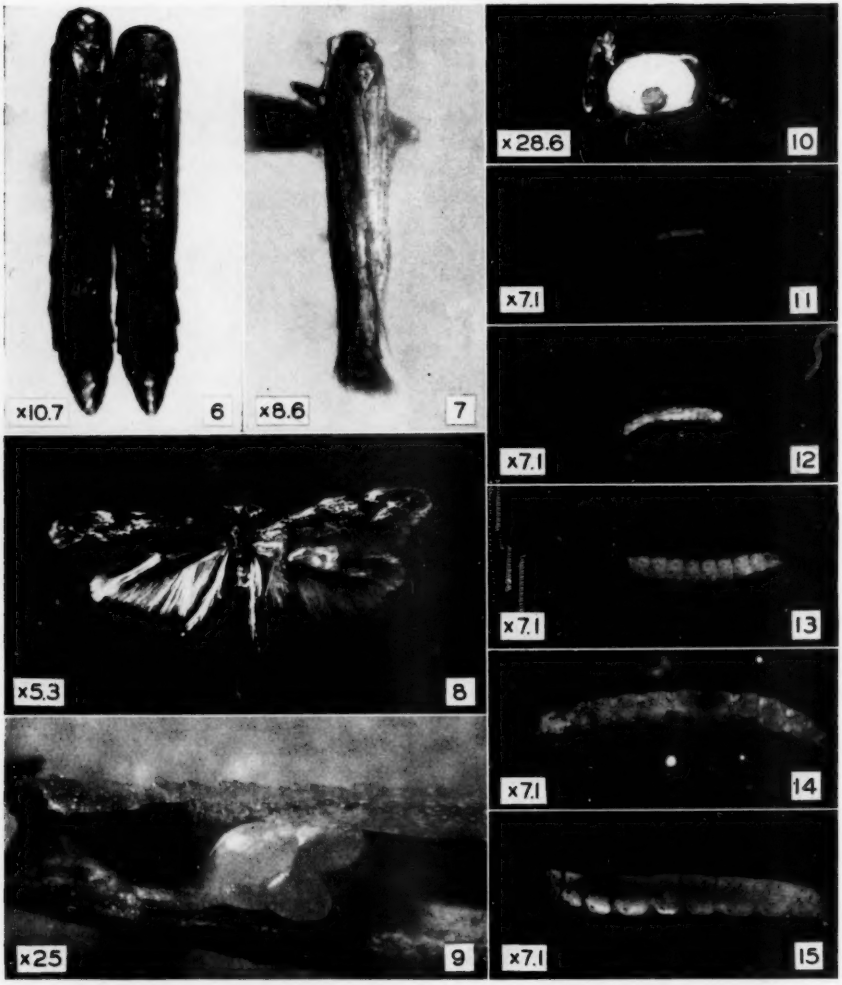


Fig. 6, Female and male pupae; Figs. 7 and 8, Needle-miner moths; Fig. 9, Cluster of eggs; Fig. 10, Egg about to hatch; Figs. 11-15, First- to fifth-instar larvae.

the latter two weeks of May. During the transfer the larva is exposed from 6 to 8 hours, usually in the daytime. Again, the larvae apparently prefer the previous year's growth but there is less selection of needles by this instar than any other. There is some evidence of movement upward in the tree crown but this is not general. The larva keeps the mine free of frass and chews a large exit hole on the convex surface of the needle close to the tip.

Fifth instar.—Fifth-instar larva are found from the last two weeks in May to late June. It is the larvae of this instar which are usually involved in the second transfer, but fourth-instar larvae may transfer also, moulting as soon as they have entered the third needle. The fifth-instar larva also enters from the flat side of the needle and hollows out the tip before mining downward. It feeds rapidly,

usually excavating the needle in two to three weeks, keeping the mine clear of frass. Once the larva has finished mining, it prepares the needle for pupation. If the exit hole has not been prepared, the larva chews a large hole on the curved surface of the needle near the tip. It then lines the inside of the lower third of the mine with silk, faces towards the exit hole, and pupates.

It is at this time that the outbreak is most noticeable. The mined needles of two years are present on the trees: the first two having darkened to a reddish-brown, the last still bright yellow. This imparts a yellowish-red tinge to the forest.

The Pupa

Description.—The pupa is approximately 6 mm. long, dark-brown to black. It is possible to sex the pupa by the position of the genital pore (Fig. 2b). The pore is on the ninth segment in the male and on the eighth in the female. In addition to this characteristic, the fused terminal segments (8th, 9th, and 10th) are relatively longer in the female. The last exuvia may be found at the base of the pupa. There is a gummy thread attaching the pupa to the wall of the mine and an incomplete silk cocoon formed by the fifth-instar larva.

Pupal perio.d—The pupae are found in the field in June and early July. Emergence begins the first week in July, so the pupal period lasts approximately from three to four weeks.

Effects of Environmental Factors

Temperature exerts a profound influence on needle-miner development throughout its entire life cycle. It is in the development and survival of eggs and larvae that temperature has its greatest effects. The normal incubation period has been determined as 15 days, but in 1948 the weather in August was cold and rainy and the incubation period was approximately 45 days. This retarded development but did not greatly affect viability since over 90 percent of the eggs hatched.

Experiments have shown that the threshold of activity of newly emerged larvae is between 59 and 65 degrees Fahrenheit. Moreover, with young larvae, 50 percent mortality occurred if temperatures below zero prevailed for longer periods than 24 hours (25). These estimates are for larvae still feeding, presumably with food in the gut. From mortality figures in the spring of the odd-numbered years and an examination of winter weather records it is obvious that hibernating larvae can withstand much colder temperatures.

Tests with third- and fourth-instar larvae have indicated that they can survive temperatures as low as -30°F. for at least 24 hours during hibernation in the fall. In the extremely cold winter of 1949-50, 90 percent kill was recorded when, for a one-week period, the maximum temperatures did not exceed -10°F. In the same month a minimum of -60°F. was recorded. The daily minimums of this month exceeded -40°F. eight times and -30°F. twelve times. These observations and laboratory experiments indicate that if temperatures in the range of -30°F. to -40°F. prevail for periods longer than 24 hours, high mortality will occur. High mortality probably would not occur in more mature larvae unless these low temperatures prevailed for several days.

It was determined that larval activity ceases in the fall and begins in the spring at about the same temperature (30). Records show that feeding ceased in the fall when maximum temperatures reached a relatively stable level below 45°F. and minimum temperatures rarely went above 32°F. In the spring the reverse is true.

It has been shown that there is no solid food in the gut during hibernation which may increase the capacity of the larvae to resist low temperatures. However, it has also been shown that diapause is readily broken and feeding induced at any time during the winter by subjecting the larvae to temperatures above the threshold of activity. An interesting point to note is that the later in the winter the larvae are tested, the longer it takes to break diapause (18).

Temperature affects the timing and duration of the two transfer periods. Perhaps the most striking example of this was in the Kickinghorse Pass in the summer of 1951, when the transfer of the third-instar larvae occurred. The weather during the feeding period prior to transfer i.e. May to July, was unsettled, with many cold, rainy periods of several days' duration. The weather was reflected in the transfer. At valley bottom there was no apparent pattern in the transfer, that is, there was no definite peak. Also, although transfer is usually effected by the whole population in two to three weeks, this transfer was spread over the whole month of July and the first two weeks of August. At the 750-foot level, the beginning of transfer was one week later, and two weeks later at the 1,500-foot level.

Field observations indicate that the larvae do not feed at temperatures less than 45°F. and records from the nearest weather station (Lake Louise) indicate that there were 69 possible feeding days prior to the beginning of transfer. On 10 of these the maximum temperature was below 45°F.; of the remaining 59, 31 days were below 60°F. which would indicate 31 days when feeding would be limited to a brief period around noon and early afternoon. Also, there were 21 days when various amounts of rain or snow fell and 10 of these were on days when the maximum temperature was above 60°F., giving an additional 10 days when feeding would be restricted. Some allowance has to be made for the heating effect of solar radiation on needle mines (7), but this would contribute to the sporadic nature of the transfer, as varying degrees of exposure and shade would cause variation in feeding. A possible explanation of this unusual transfer may be found in the general effects of the movement of weather systems through this pass.

There have been two instances of off-year maturation of the needle miner, one in the Bow Valley of Banff National Park in 1949 (5), and the other in the Kickinghorse Pass of Yoho National Park in 1951 (30). Two theories have been advanced for their occurrence. The first is genetic in character (29), the second climatological. The bimodality of the head capsules in fourth- and fifth-instar larvae suggests heterogeneity in the population. It has been postulated that there are two strains of needle miner, one requiring two years to mature, the other capable of maturing in one year, weather permitting. Conditions in 1949 and again in 1951, (but in different areas) permitted the one-year stock to mature. However, there are approximately equal numbers of larvae represented in the two modes and the number of larvae maturing in one year in either region was much less than would be expected if the bimodality was accepted as an indication of heterogeneity. The second theory is that the needle miner is capable of one-year development if conditions are favourable. Present investigations have shown that weather conditions, principally winter minima, play an important part in distribution and abundance. The occurrence of the off-year development in the Bow Valley was restricted to a relatively uniform area topographically, and that in the Kickinghorse Pass was very limited in extent. This suggests the action of local climate. Further studies are necessary to test this hypothesis.

Wind exerts a marked influence on moth behaviour. It was noted that moths were generally quiescent when there was even a light wind and this could have

an influence on retarding the outward spread of an infestation. The spread of the needle miner in the five flight years under observation indicates that there is relatively little wind transportation of the moths. The rapid build-up of populations in valley bottoms since 1942, however, may indicate possible transportation by down-slope winds.

Control

Experiments with chemical control on all stages of the insect have met with limited success (4, 26). Due to the inaccessibility of the miner throughout most of its life cycle, and the inconstant nature of the larval transfer, the only period when control might be effected is during moth flight. For successful control, any program designed to eradicate the adult stage would require extremely precise planning and rapid coverage of the whole area; this would be practically impossible.

Winter temperatures play an important part in controlling the distribution and abundance of the needle miner. In each of the two winters during larval development the mortality is about 20 percent, accounting for approximately 35 percent of the total population. Occasionally, however, catastrophic mortality occurs, as in the winter of 1949-50, when between 90 and 100 percent of the larvae were killed at the lower elevations in Banff National Park. Because of the nature of this climatic control, any additional measures should be concentrated along the middles of the slopes.

Biotic control shows some promise for the future. Fifteen species of parasites have been found in Canadian populations. However, most of these are rare, over 90 percent of the parasite population being composed of five species: *Copidosoma* sp., *Neoderostenus* sp., *Sympiesis* sp., *Apanteles californicus* Mues., and *Apanteles* sp. (23, 31, 32). Although liberations of parasites supplied by the Biological Control Unit from other outbreaks are small in proportion to actual populations, they have given encouraging results. To date, only species that are already native have been liberated which makes it impossible to differentiate between natural population rise and effectiveness of liberations.

No virus disease has ever been isolated from Canadian needle-miner larvae, but a virus has been isolated from Californian material at the Laboratory of Insect Pathology at Sault Ste. Marie, Ontario, and is being tested in the laboratory and the field.

Acknowledgments

It is a great pleasure to acknowledge the assistance given by K. Graham of the University of British Columbia. Sincere thanks are also due those members of the Calgary Laboratory of Forest Zoology who contributed to various phases of the study, particularly G. R. Hopping and R. F. Shepherd and also W. R. Henson of the Sault Ste. Marie Laboratory.

References

1. Annual reports of the forest insect survey, 1942-1952 incl. Div. of Forest Biology, Science Service, Dept. of Agric. Ottawa.
2. Beck, S. O. 1950. Nutrition of the European Corn Borer, *Pyrausta nubilalis* (Hbn.) II. Some effects of diet on larval growth characteristics. *Phys. Zool* 23(4): 335-361.
3. Busck, August. 1914. Description of new Microlepidoptera of forest trees. *Proc. Ent. Soc. of Wash.* 16(4): 143-150.
4. Campbell, D. K. 1947. Lodgepole needle miner. Bi-Monthly Progress Report, Div. of Ent. Dept. of Agric. 3(5) Ottawa.
5. Graham, K., and G. R. Hopping. 1949. Lodgepole needle miner. *Ibid.* 5(4).
6. Grant, J., and P. F. Larue. 1949. Lodgepole needle miner (distribution). *Ibid.* 5(6).
7. Henson, W. R., and R. F. Shepherd. 1952. The effect of radiation on the habitat temperatures of the lodgepole needle miner, *Recurvaria milleri* Busck (Lepidoptera: Gelechiidae). *Can. Jour. Zool.* 30: 144-153.

8. Hinton, H. E. 1946. On the homology and nomenclature of the setae of lepidopterous larvae, with some notes on the phylogeny of the Lepidoptera. *Trans. Roy. Ent. Soc.* (London). 97(1): 1-37.
9. Hopping, G. R. 1945. Lodgepole pine needle miner. Bi-Monthly Progress Report, Div. of Ent. Dept. Agric. 1(2) Ottawa.
10. ——————— —— Lodgepole pine needle miner. *Ibid.* 1(6).
11. ——————— 1946. The lodgepole pine needle miner in the Canadian Rocky Mountain Parks. *Ent. Soc. of B.C. Proc.* (1945). Vol. 42: 1-2.
12. ——————— —— The lodgepole needle miner in western Canadian Parks. *Div. of Ent. Proc. Publ.* No. 59 Ottawa.
13. ——————— —— Lodgepole needle miner. Bi-Monthly Progress Report, Div. of Ent. Dept. Agric. 2(4) Ottawa.
14. ——————— 1948. Rocky Mountain region. *Ibid.* 4(4).
15. ——————— 1950. Timber types in relation to insect outbreaks in the Canadian Rocky Mountains. *81st Annual Rept. Ent. Soc. of Ontario (Proc.)*: 72-75.
16. ——————— —— Lodgepole needle miner. Bi-Monthly Progress Report, Div. of Ent. Dept. Agric. 6(3) Ottawa.
17. ——————— —— Lodgepole needle miner. *Ibid.* 6(5).
18. ——————— 1951. Lodgepole needle miner. *Ibid.* 7(1).
19. McGuffin, W. C. 1949. Forest insect survey. *Ibid.* 5(2).
20. ——————— —— *Ibid.* 5(5).
21. ——————— 1950. Forest insect survey. Bi-Monthly Progress Report, Div. of Forest Biology, Science Service, 6(6) Ottawa.
22. ——————— 1951. *Ibid.* 8(1).
23. McLeod, J. H. 1951. Notes on the lodgepole needle miner, *Recurvaria milleri* Busck (Lepidoptera: Gelechiidae) and its parasites in Western North America. *Canad. Ent.* 83(11): 295-301.
24. Patterson, J. E. 1921. Life history of *Recurvaria milleri* Busck, the lodgepole pine needle miner in the Yosemite National Park, California. *Jour. Agr. Res.* 21(3): 127-143. Wash. D.C.
25. Shepherd, R. F. 1950. Lodgepole needle miner, *Recurvaria milleri* Busck. Bi-Monthly Progress Report, Div. of Ent. Dept. Agric. 6(6).
26. Stark, R. W. 1948. Lodgepole needle miner. *Ibid.* 4(5).
27. ——————— —— Lodgepole needle miner. *Ibid.* 4(6).
28. ——————— 1949. Lodgepole needle miner. *Ibid.* 5(1).
29. ——————— and K. Graham. 1949. Lodgepole needle miner (bionomics). *Ibid.* 5(6).
30. ——————— and R. W. Reid. 1951. Lodgepole needle miner. *Ibid.* 7(3).
31. ——————— 1951. Parasitism of the lodgepole needle miner. *Ibid.* 7(6).
32. ——————— 1952. Lodgepole needle miner parasites. *Ibid.* 8(4).
33. ——————— —— Lodgepole needle miner larval instars. *Ibid.* 8(6).
34. ——————— —— Sequential sampling of the lodgepole needle miner. *For. Chron.* 28(2): 57-60.
35. ——————— —— Analysis of a population sampling method for the lodgepole needle miner in Canadian Rocky Mountain Parks. *Canad. Ent.* 84(10): 316-321.

(Received April 28, 1953)

Effects of the Weather of the Coldest Month on Winter Mortality of the Lodgepole Needle Miner, *Recurvaria* sp., in Banff National Park[1]

By W. R. Henson[3], R. W. Stark[3], and W. G. Wellington[2]

In the Canadian Rocky Mountain National Parks, the lodgepole needle miner has a two-year life cycle, so that larvae of each generation are exposed to two successive winters. Although there is no doubt that mortality of these overwintering larvae is directly attributable to a period of low temperature, there has been some doubt as to whether the bulk of the mortality occurs during the coldest part of the winter, or whether it occurs during periods of low temperature during the late autumn or early spring. Although spring and autumn mortality undoubtedly take place, estimation of the relative importance of mortality during the various seasons must await successive sampling throughout the three seasons. Nevertheless, in the absence of such data, we wish to present evidence that points to the major importance of the weather of the coldest month of the winter to not only the amount but also the vertical distribution of larval mortality.

Evaluation of this evidence requires some knowledge of the migratory weather systems that affect the eastern slopes of the Rockies. Consequently, a brief outline of this necessary meteorological background is presented before the mortality data are discussed. The winters of 1948-49 and 1949-50 are used as examples, because records of vertical variations in mortality along different slopes are more complete for these than for previous years. The discussion is restricted to the part of the Bow Valley that lies within Banff National Park, Alberta.

Table I

Monthly Mean Air Temperatures (Fahrenheit) At Lake Louise Junction During the Winters of 1948–49 and 1949–50

	N	D	J	F	M
1948–49.....	19.1	1.8	− 2.4	5.2	22.9
1949–50.....	30.5	5.3	−19.3	13.4	17.5

In the Bow valley, the winters of 1948-49 and 1949-50 were both comparatively cold. Table I lists the monthly mean air temperatures compiled from records taken at Lake Louise Junction. These records show that January was the coldest month of each winter, and that this month was colder in 1950 than in 1949. Apart from this month, and, to a lesser extent, the month of March, the winter of 1949-50 actually had higher monthly mean temperatures than did the previous winter. This is convenient for the present purposes, since it sets the observed difference during the coldest month in opposition to the observed seasonal difference, a point which should make the evaluation of the effect of the coldest month more critical.

The available series of printed weather maps for the two winters is incomplete, but a sufficient number is available for each month so that reliable comparisons of the occasional changes in invading air-mass types may be made. Table II contains pertinent air-mass data abstracted from the daily weather maps.

1Contribution No. 97, Division of Forest Biology, Science Service, Department of Agriculture, Ottawa, Canada.

2Forest Insect Laboratory, Sault Ste. Marie, Ontario.
3Laboratory of Forest Zoology, Calgary, Alberta.

TABLE II

Records of Frontal Passages and of the Incidence of Polar Continental Air Over the Bow Balley During the Winters of 1948–49 and 1949–50.

Winter	Month	Total No. Daily Maps	Total No. of All Types of Frontal Passages	No. cP Cold Fronts	No. Days Area in cP Air
1948–49.....	N	25	13	7	10
	D	25	12	7	16
	J	24	16	9	15
	F	24	13	6	16
	M	25	7	2	11
1949–50.....	N	25	4	0	0
	D	23	9	5	14
	J	26	3	2	25
	F	24	8	4	8
	M	27	4	1	14

In Table II, the column "frontal passages of all types", includes warm and cold fronts of polar maritime origin, and cold fronts of polar continental origin. The next column lists only the cold fronts of polar continental origin. It is clear that each month of the winter of 1948-49 had much more frontal activity than did the corresponding months of the winter of 1949-50. Furthermore, enough of the fronts were of continental origin to ensure that the area was frequently occupied by cold polar continental air. The total amount of all types of frontal activity, however, shows that this air seldom remained for long over the area, but was replaced either by fresh outbreaks, or by milder polar maritime air.

On the other hand, the winter of 1949-50 was characterized by a reduced amount of frontal activity. Such a reduction increases the interval between frontal passages, and permits the air that followed one front to stagnate for days or even weeks, instead of moving off ahead of another front after one or two days, as is more usual. In the table, this tendency towards stagnation is clearest in the extreme instance, January, 1950.

The table shows, then, that the "coldest" months of two successive winters may have their low temperatures produced in somewhat different ways. In the area in question, a good supply of polar continental air is the basic requirement, but it may produce its effects either by appearing in successive outbreaks, or by invading only a few times, but stagnating after each invasion. In general, stagnation of cold air over the eastern slopes of the Rockies produces lower temperatures than successive invasions of cold air, because the continued radiational cooling through the stagnating air continues to lower the temperatures of surfaces

TABLE III

Comparison of the Percentage Mortalities at Valley Bottom at Three Locations In the Bow Valley After the Winters of 1948–49 and 1949–50

	Massive Mtn.	Mt. Eisenhower	Lake Louise
1948–49.....	9.8	31.6	23.1
1949–50.....	100.0	99.9	100.0

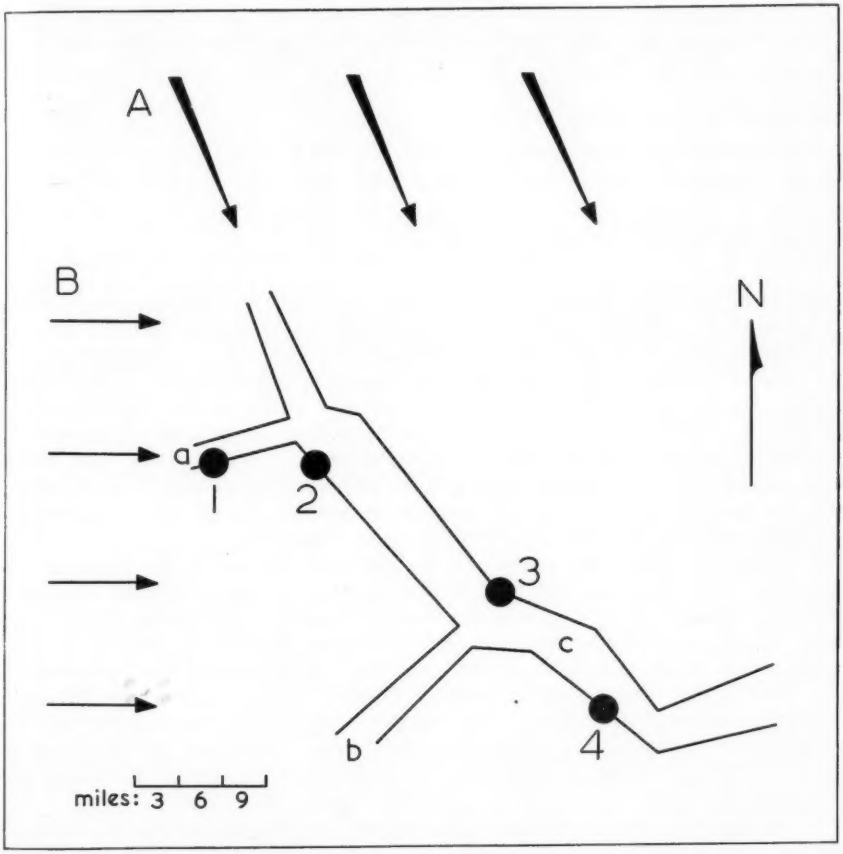


Fig. 1. Diagrammatic presentation of the Bow Valley in Banff National Park, constructed by eliminating irregularities along the 6000-ft. contour. A, Polar continental air; B, Polar maritime air; a, Kicking Horse Pass; b, Vermilion Pass; c, Bow Valley; 1-4, locations of the infestations: 1, Kicking Horse; 2, Lake Louise; 3, Mount Eisenhower; 4, Massive Mountain Valley bottom altitudes above sea level are: 1, 4500 ft.; 2, 5051 ft.; 3, 4676 ft.; 4, 4593 ft.

and of the lower levels of air. Thus, January, 1950, a month of prolonged stagnation, was colder than January, 1949, a month of continued frontal activity.

With this in mind, it is of interest to turn briefly to the figures for needle miner mortality at three different locations along the bottom of the Bow Valley. These are shown in Table III, for the two winters, and the effects of stagnating air near the surface are clear.

This leads to a consideration of the effects of the local topography on the behavior of weather systems. Fig. 1 will enable the reader to follow the subsequent discussion more easily. It is a diagram of most of the Bow Valley contained in Banff National Park. It was constructed by tracing the 6000-ft. contour along the slopes on both sides of the valley and along the eastern ends of the two major trans-divide passes that open into it from the west, and then eliminating all the minor irregularities. The diagram also shows a simplified version of the direc-

TABLE IV

Percentage Mortality of Overwintering Larvae on a Slope of Massive Mountain At Different Altitudes Above Valley Bottom,* 1948–49 and 1949–50.

Altitude, in feet, above valley bottom.	0	500	1000	1500
Winter, 1948–49	9.8	16.6	11.6	28.3
Winter, 1949–50	100.0	91.0	92.6	87.0

*The valley bottom at Massive Junction is 4593 ft. above sea level.

tions of approach of the two major air-mass types, and the locations of the four infestations for which mortality data are presented in subsequent tables.

Of the four locations, Massive Mountain is considered to be representative of most of the Bow Valley, because of its comparatively sheltered position with respect to the mouths of the two major passes. Variations in mortality with height on a slope of Massive are shown in Table IV. (The methods by which mortality estimates for this and subsequent tables were obtained have been described (1, 2), and depend in part upon sequential sampling. Consequently, there is no fixed sample size: for example, in 1948-49, 11,266 larvae had to be checked, whereas, in 1949-50, only 5,506 were examined.)

Table IV shows that there was an effective reversal in the variation in mortality with height on this slope during the two successive winters. Because Massive Mountain is in a relatively protected location with respect to the two trans-divide passes, the temperature profile along its slope is not affected by any trans-divide peculiarities in air current structure. When a cold front passes over the Bow Valley, the top of the slope of Massive becomes colder than its base, while the new air mass is fresh. This difference diminishes to near equality soon after frontal passage, but it persists for a short time. Therefore, during a month in which cold fronts are plentiful, the top of Massive is frequently colder than its base, and the result is shown in the mortality figures for 1948-49.

On the other hand, if the new cold air mass stagnates over the valley, instead of moving on, the greatly increased radiational cooling of all surfaces not only lowers the temperatures generally, but also forms a more and more pronounced temperature inversion in the lower air. Nocturnal temperatures near the valley floor fall much below those higher in the air, and, if the air remains long enough, this inversion may even persist into the daytime. Furthermore, if the air is not soon replaced, the depth of this pool of very cold air steadily increases. The result is shown in the mortality figures for 1949-50.

The slope of Massive Mountain is both sheltered and relatively shaded. The slope of Mount Eisenhower presents a more complicated situation. It has a precipitous crown that is sunlit for much of the day and, consequently, is more subject to convective winds. More important, it lies directly across the Bow Valley from the mouth of the Vermilion Pass, and so is directly in the path of both freshly arrived western weather systems and down-slope nocturnal drainage winds of considerable velocity. In addition, the valley floor at this point is higher than at the base of Massive.

The effects of these factors are expressed in the mortality figures shown in Table V. The clearest effect is that produced by the colder stagnating air during 1949-50, which caused mortality at Mount Eisenhower almost as great as that recorded at Massive. However, the overall increase in mortality during this very cold month obscured the different effects of other factors which are more

apparent in the 1948-49 mortality records for the two infestations. During 1948-49, there was some effect of colder air at the higher valley floor elevation at Mount Eisenhower, but this effect was slight compared with that resulting from proximity to the mouth of the Vermilion Pass.

Inspection of the 1948-49 mortality records for the two slopes (Tables IV and V) shows that the trends of the altitudinal variation in mortality above the 500-ft. level are similar on both. Below that level, there is a considerable difference between both the trends and the amounts. Cold air drainage down the narrow Vermilion Pass takes place at night under a variety of weather conditions, and this additional nocturnal chilling affects objects in the path of the drainage both on the valley floor and on the lowest opposite slopes. Mount Eisenhower is directly in the path of this drainage, and therefore it cannot be considered typical of most of the Bow Valley, because its needle miner infestation shows typical mortality trends only on the upper slopes during weather that produces moderate mortality in more sheltered parts of the main valley.

TABLE V

Percentage Mortality of Overwintering Larvae on a Slope of Mount Eisenhower At Different Altitudes Above Valley Bottom,* 1948–49 and 1949–50.

Altitude, in feet, above valley bottom..	0	500	1000	1500
Winter, 1948–49.....	31.6	27.6	20.0	24.0
Winter, 1949–50.....	99.9	78.8	64.8	61.9

*The valley bottom at Castle Junction is 4676 ft. above sea level.

The records for the infestation near Lake Louise are shown in Table VI. The Lake Louise slope on which the sampling was done is on the shoulder of Mount St. Piran, just south of the eastern end of the Kicking Horse Pass. The two lower sampling points lie directly in the mouth of the Lake Louise Valley, which is backed by mountains that have extensive glaciers. Consequently, nocturnal drainage of cold air down the valley is common during any month of the year, and it accounts for the variation in mortality shown on the Lake Louise lower slope during the winter of 1948-49. Because of this drainage, the variation for that winter is more comparable to that found on the lower part of Mount Eisenhower than to that on Massive.

The records from the whole slope for the winter of 1949-50 once again show the marked effects of excessive radiation. However, the upper slope records for both winters suggest that air currents from the nearby Kicking Horse Pass affected the local climate. Some complicated trans-divide air currents are indicated, but

TABLE VI

Percentage Mortality of Overwintering Larvae on the Slopes Near Lake Louise At Different Altitudes Above Valley Bottom*, 1948–49 and 1949–50.

Altitude, in feet, above valley bottom.	0	500	1000	1500
Winter, 1948–49.....	23.1	18.5	16.2	8.4
Winter, 1949–50.....	100.0	61.1	41.3	63.4

*The valley bottom at Lake Louise Junction is 5051 ft. above sea level.

any attempt to analyse these would be based on sheer speculation, in the absence of adequate local upper air data.

The lack of such data from the site of the Kicking Horse infestation makes it impossible to do much more than point out the somewhat confused mortality patterns shown in Table VII, and note that the complex relationships between the air masses on either side of the Great Divide during the two types of weather would repay further study. The only really clear point shown in Table VII is that, during 1949-50, there was far less stagnation of air in the pass than there was in the Bow Valley. This greater air movement is to be expected, in view of the frequent trans-divide air-mass differences.

TABLE VII

Percentage Mortality of Overwintering Larvae on the Slopes of the Kicking Horse Pass At Different Altitudes Above Valley Bottom,* 1948-49 and 1949-50.

Altitude, in feet, above valley bottom..	0	500	1000	1500
Winter, 1948-49.....	14.1	14.3	44.6	—†
Winter, 1949-50.....	24.6	43.4	30.8	—†

*The valley bottom at the location of the infestation is 4500 ft. above sea level.
†No lodgepole pine at this altitude.

Because of the severe mortality near Lake Louise during the winter of 1949-50, it was impossible to obtain detailed estimates of mortality during the following winter. However, events since then give some indication of what must have occurred. The winter of 1950-51 was characterized by a succession of maritime air invasions during the coldest month, and, consequently, the mean temperature of this month rose to 14.8°F. at the Lake Louise valley bottom. This implies more moderate conditions on the slopes. Indeed, although a needle miner population did not reappear at valley bottom, the population at higher levels made a substantial recovery, for, by the summer of 1952, a heavy infestation was general about 500 ft. above the valley floor. (The winter of 1951-52 had some polar continental air during its coldest month, but the monthly mean temperature in the valley was 10.2°F., which did not produce inordinate mortality in the recovering population.)

The foregoing synthesis has linked the observed mortality trends in different parts of the Bow Valley and the local meteorology in such a way that the following hypothesis can be subjected to further testing. Briefly, if the coldest month of the winter exerts as powerful an influence as is suspected, then not only should the amount of mortality be closely linked with the temperature of the month but also the upslope distribution of mortality should vary from year to year in relation to the type of weather that occurs during the month. This can be tested annually for a few years, and the basic hypothesis modified, if need be, to take into account observed effects of unusual autumn or spring weather. For further reference during these tests, we append a few additional points that are implied by the hypothesis. The accuracy of the predictions will be a measure of the validity of the hypothesis.

Because of the occasional reversals in the types of circulation that affect the area during its coldest winter month, the heaviest persistent infestations of needle miner in the Bow Valley should be centred in the middle range of altitudes on the sheltered slopes. Indeed, the original infestation took this form. The zone

in which the larvae should always be most susceptible to winter killing is that of the valley bottom and its adjacent lower slopes, throughout most of the main trench of the Bow. In the lower Bow Valley, infestations on the upper parts of the slopes frequently should experience increased mortality, but it is doubtful if this would ever be as severe as the occasional catastrophic mortality on the valley bottom. Near the mouths of side valleys that have much nocturnal air drainage, additional mortality on the valley bottom and lowest slopes may be expected in otherwise moderate years. In or near the major passes, the pattern of mortality will always be more complex and, for some time, much less predictable.

Most of the Bow Valley is relatively sheltered. In these parts, it is clear that the apparently least susceptible zone, the middle altitudes on the slopes, should provide the reservoir from which re-infestation of the other zones could occur through up-slope and down-slope transport of the flying adults. Consequently, any serious control measures should be concentrated within this zone, and this is particularly true of liberations of parasites and disease organisms. If the populations in the middle zone could be limited, it is improbable that the insect could ever reach infestation proportions outside that zone.

Conclusions

1. In the main part of the Bow Valley, the vertical distribution of temperature is a function of the predominant type of general circulation. Thus, during a month characterized by frequent, but rapid, invasions of polar continental air, the upper slopes are more often colder than the valley floor. On the other hand, stagnating air of any type produces extremes of cold on the valley floor, and these are much more severe when the air is of polar continental origin. (Invading maritime air warms the upper slopes so that, effectively, the valley bottom is colder than the upper slopes at such times. Thus, effects are produced that are similar to, but more moderate than, the effects of stagnating polar continental air.)

2. In the Bow Valley, winter mortality seems to be distributed in the same way as the zones of extreme cold that occur during the coldest winter month. Because the dominant type of circulation during this month may be different in different years, the zone of most extreme cold may occur either at valley bottom or at the tops of the slopes. Consequently, greatest mortality should occur in either of these locations, although it should occasionally be exceptionally great at valley bottom. Best survival should occur most consistently along the middle of the slopes.

3. This middle zone then, should constitute the most persistent reservoir for re-infestation of the other zones and, therefore, the most serious attempts to control the insect should be concentrated in it.

4. In or near the major passes that enter the Bow Valley from the west, the air flow is more complicated and, therefore, the vertical distribution of mortality is much less predictable than it is in the rest of the valley.

Acknowledgments

We wish to thank G. R. Hopping, of the Calgary Laboratory of Forest Zoology, for his helpful discussions, and for providing detailed records collected during earlier years. Miss P. M. G. West assisted with basic climatological analyses.

References

1. Stark, R. W. Sequential sampling of the lodgepole needle miner. *Forest Chron.* 28: 57-60. 1952.
2. ———— Analysis of a population sampling method for the lodgepole needle miner in Canadian Rocky Mountain Parks. *Can. Entomol.* 84: 316-321. 1952.

(Received April 28, 1953)

A Review of the Life-history and Habits of the Horn Fly, *Siphona irritans* (L.) (Diptera: Muscidae)[1]

By J. McLintock[2] and K. R. Depner[3]
Veterinary and Medical Entomology Section, Laboratory of Entomology
Lethbridge, Alberta

Introduction

A co-operative investigation to discover the factors necessary for egg production in the horn fly, *Siphona irritans* (L.), was begun in 1950 at the Lethbridge laboratory and the Department of Bacteriology, University of Alberta, Edmonton. Although there is an extensive literature on the horn fly, comparatively few publications deal exclusively with its life-history and habits. Information on the biology of this insect is found in a widely scattered literature dealing with muscids or dung-breeding insects in general. The dearth of information in recent years on this economically important insect may be caused in part by the fragmentary literature. This paper is a review of the available information on the life-history and habits of the horn fly, along with observations of the authors.

The horn fly is a well-established pest of cattle in most countries of the New World from Venezuela (Fiasson, 1943) to Canada, and in the Old World from North Africa to Lapland (Bezzi, 1911). It is generally considered to be one of the most serious pests of cattle wherever it occurs. Both sexes of the fly suck blood, and damage and loss attributed to it include loss in condition, reduction of one-quarter to one-half in milk yield, and production of sores caused by the animals rubbing and licking themselves constantly to allay irritation of the bites (Riley, 1889a, b; Smith, 1889; Fletcher, 1892). The loss of blood may be considerable when flies are abundant and has been estimated to be seven quarts per day, or 312 U.S. gallons per year, from a heavily infested herd of 500 animals (Annand, 1941, p. 94; Bruce, 1942; Marlatt, 1910). Bruce (1940) and Fiasson (1943) mentioned digestive disorders in the cattle caused by the flies interfering with feeding and resting. In southern Alberta, ranchers claim that the attacks of this fly reduce the calf crop, because of the apparent preference of the flies for bulls.

Morris (1918) showed that the horn fly is capable of transmitting anthrax after biting an infected animal. This is the only disease with which horn flies have been associated and their role, if any, in its natural spread is unknown. *Lyperosia* spp. have been suspected of transmitting trypanosomes (Bezzi, 1911; Jack, 1917), but the horn fly has not yet been implicated in these infections.

Cattle are the principal hosts of the horn fly and the dark-coloured breeds are said to be attacked more than the lighter-coloured (Bruce, 1940; Marlatt, 1910). Hammer (1942) concluded that temperature and colour played only a secondary part in the attraction of the host. But on black-and-white cattle it usually seeks out the black spots, where the hide temperature is undoubtedly higher (Thomsen, 1938). Our observations in southern Alberta and those of Hammer (1942) in Denmark indicate that horn flies are more abundant on bulls than on cows or calves, and on cows the shorter-haired breeds and individuals are preferred. But in Venezuela, Fiasson (1943) found that bulls were attacked

[1]Contribution No. 3083, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.
[2]Entomologist, now of the Veterinary and Medical Entomology Unit, Ottawa.
[3]Assistant Entomologist.

less than cows. Horses, mules, sheep, goats, dogs, and man are also attacked occasionally (Bruce, 1940, 1942; Hammer, 1942; Riley, 1889a; Marlatt, 1910; Thomsen, 1938).

The horn fly was apparently first described by Linnaeus in 1758 (Bezzi, 1907). It was known in southern France in 1830 (Riley, 1889a; Smith, 1889). It was introduced into North America on cattle imported from Europe between 1884 and 1886, and by 1898 it had spread over the continent from Canada to Texas, from Massachusetts to the Rocky Mountains, and to Honolulu (Marlatt, 1910). It was first reported in Canada from Oshawa, Ontario, in 1892 (Fletcher, 1892), and is now found with its host almost everywhere in Canada. It is apparently rare in the vicinity of Edmonton, Alberta, but a severe infestation has been reported at Gadsby, about 60 miles southeast of Edmonton (MacNay, 1952). Edmonton (Lat. 53°33′N) may therefore be near the northern limit of the distribution of this fly in Canada. Myers (1938) believed that the horn fly was introduced into the West Indies on cattle from the United States. According to Fiasson (1943) it was introduced into Venezuela about 1937, on cattle from Colombia. The horn fly always travels with its host.

During the early years of this century a number of publications appeared containing observations on the taxonomy and biology of the horn fly. We have not seen all of these, but for anyone interested in finding the complete literature the references given by Bezzi (1907, 1911) and Hammer (1942) should be of considerable help. Both *Siphona irritans* and *Haematobia stimulans* (Meig.) occur in Europe, where they have a similar geographic distribution and are so alike in appearance and habits that some observers have confused the two species. This confusion is seen in the complicated synonymy of the species, and should always be kept in mind in reading the European literature. For example, some of Wilhelmi's (1917) observations on the flies were sufficiently at variance with those of other writers to suggest that he had observed mixed populations. The flies described by him were much scarcer on cattle in sheds than on cattle in the field; the flies occurred, apparently in large numbers, on grass, weeds, and bushes; he found the flies resting on walls, with the head directed upward. These are habits usually ascribed to *H. stimulans*.

Little was known about the life-history and habits of the horn fly until Riley (1889a, b) and Smith (1889, 1890) published observations made in the eastern United States. These observations have been widely quoted and, together with the summary published by Marlatt (1910), have formed the basis of textbook descriptions. In a series of papers published between 1938 and 1948, Bruce contributed more facts in the life-history and habits. Other observations have been published from time to time, usually in reports on muscids or dung-breeding insects in general or as incidental observations in control studies. The more extensive of these have been the works of Larsen (1943a, b); Thomsen and Thomsen (1937); Larsen and Thomsen (1941); Thomsen (1938); Hammer (1942) and Mohr (1943).

The Adult

All observers are agreed that the horn fly is an obligate blood-sucking parasite of cattle. It remains on its host night and day and in this respect differs from the closely related, but exclusively European, species *Haematobia stimulans*. The latter leaves the cattle at night and when they enter buildings (Hammer, 1942; Thomsen, 1938). Bruce (1938) concluded from observations made during trapping experiments that the adults of *Siphona irritans* did not travel any considerable distance under range conditions. Hammer (1942) indicates that they will not travel even a few hundred metres from their host.

The stimuli that attract horn flies to their host are unknown. Krijgsman and Windred (1933) found that the closely related species *Lyperosia exigua* de Meij. could detect the smell of their hosts "over a distance". Bax (1937) found that *Glossina swynnertoni* Austen reacted to both the scent and sight of the host (*Glossina* and *Siphona* are also closely related taxonomically; Grünberg (1906) proposed the generic name *Glossinella* for the horn fly).

The flies rest on parts of the body of the host that cannot be reached by the head or tail; that is, slightly behind the shoulders, at the bases of the horns, on the middle of the belly, and low on the hind legs. In general, the flies seem to seek the shaded and sheltered places on the cattle (Hammer, 1942; Thomsen, 1938). Riley (1889a, b) and Marlatt (1910) found the flies resting on the back between head and shoulders, and under the belly during a rainstorm. The flies feed on the back, flanks, legs, and dewlap; or on the thigh, "back belly", and udder when the cow is lying down. All these are places with thin or short hairs (Hammer, 1942). Our observations in southern Alberta agree closely with those of Hammer (1942) in Denmark. When the weather is cloudy or cool the flies always rest on the backs of the cattle. But when the weather is bright and sunny, their resting place seems to depend on the air temperature. At air temperatures up to 19°C., we found the flies resting on the backs of the cattle. At air temperatures of 26° to 29°C., the flies were always underneath on the belly, on the lower parts of the hind legs, and on the scrotum or the udder. On one occasion, during a rain when the air temperature was 9°C., the flies were half-buried among the long hairs on the back, sides, and neck and in the grooves at the sides of the base of the tail. When disturbed, the flies flew up quickly but returned immediately to the backs of the cattle. On this occasion no flies were seen on the belly or on the lower parts of the hind legs.

The fly spends most of its time on the body surface of its host. The physical nature of that environment is of interest because of its possible effect on egg production and longevity of the flies. Hammer (1942) has suggested that the cow is surrounded by a "mantle" of humidity, but there are no measurements to support this concept. There are temperature measurements that indicate that the hair temperature of cattle differs on different parts of the body and under different weather conditions. Hammer (1942) found (with a mercury thermometer) that the hair temperature in the angle between the udder and the belly remained fairly constant at about 37°C., in the elbow angle at 35° to 36°C., and on the inner side of the thigh at 34° to 36°C.; these are places where the flies prefer to feed. When the air temperature was 14.3°C. in the sun and 12.3°C. in the shade, the hair temperature on the flanks was 30°C. in the shade and 37° to 40.5°C. in the sun; under these conditions most of the flies were in the udder corner and fewer in the elbow corner. On cool nights the flies gathered in the angles of the udder and at the elbow and at the bases of the horns; in the latter places the temperature was over 30°C. In southern Alberta the temperature of locations on the host where the flies rest varies from 34° to 39°C., measured with a mercury thermometer. Our observations and those of Hammer suggest that the flies prefer a temperature of about 37°C.; one would expect the moisture requirements to be very high at such a temperature. Thompson, Worstell, and Brody (1951) have provided more accurate information on the body surface temperatures of cattle. Using thermocouples, they compared the skin and hair temperatures of dairy cattle with that of the surrounding air in a barn. Readings were taken on six different locations (not including the udder and elbow angles) on each of six cows (three Holstein and three Jersey) and averaged. At an air

temperature of 0°F. the hair temperature averaged about 50°F.; at an air temperature of 103°F. the hair temperature (and the skin temperature) were also 103°F. At air temperatures of 52.7° and 75.7°F. the hair temperatures on the Holsteins were 78.4° and 90.3°F. respectively. These measurements illustrate the effect of ambient air temperatures on the hair temperature of cattle. But these effects are modified by sun and wind; for example, when the air temperature in the sun in a pasture in southern Alberta was 29°C. (84.2°F.), the temperature of the hair on the back of a cow was 43.5°C. (110.3°F.). In the study of Thompson *et al* (1951) an ambient air temperature of 84.7°F. gave a hair temperature of 93.9°F. Again, in a pasture with a light breeze blowing, the air temperature in the sun was 24°C. (75.2°F.), and on the shoulders of a cow the temperature on the leeside was 37°C. (98.6°F.), and on the windward 35°C. (95°F.).

The horn fly derives its name from a habit that the flies sometimes have of clustering at the bases of the horns (Riley, 1889a, b; Marlatt, 1910; Thomsen, 1938). According to Riley (1889a, b) and Marlatt (1910), the horn-clustering habit is only noticed in the spring and early summer when the flies are very abundant and average more than 100 flies per animal. But in Haiti, Myers (1938) observed the habit only when the flies were least abundant (50 to 100 per animal) and usually in cool (the maximum annual temperature of the locality is 31°C., the minimum 4.5°C., and the annual mean temperature about 18.4°C.), misty weather or on chilly, shaded slopes. Bezzi (1911) never observed the flies clustering on the horns of cattle in Italy. Fiasson (1943) states that the fly does not rest at the bases of the horns in Venezuela. In Canada Hearle (1938) noted, "Since dehorning has come so much into practice the common name of the insect is not quite so suitable as it used to be." In southern Alberta we observed the habit in only one locality. This was in a small herd of purebred Herefords on a farm near Lethbridge. The herd grazed on a flood plain of the Old Man River, in a place difficult to reach, and observations were made on only three days. The weather was sunny and warm with little wind during these three days. Air temperature measurements during the observations ranged from 64° to 95°F., and relative humidity from 25 to 66 per cent. The cattle were heavily infested with horn flies; on 28 of the animals rough counts ranged from 150 to 2,100 flies, or an average of about 500 flies per animal. On these three days the flies were more conspicuous on the horns in the mornings than in the afternoons, but even in the mornings all the cattle did not have flies on the horns. Furthermore, the number of flies on the horns bore no relation to the total fly population on the host. When rough counts of the total number of flies on each animal were being made, the number of flies on the horns was also noted. Heifers with total populations of about 200, 300, and 500 flies had no flies on the horns; another heifer, with a total population of about 150 flies, had 12 flies on each horn; the bull had a total fly population of about 2,100 but had only six flies on each horn, and a heifer with a total population of about 300 flies had 20 flies on each horn. The eco-climate around each host may determine whether clustering on the horns will or will not take place. In Denmark, Hammer (1942) noticed that the flies are far less concentrated on the horns during the day than at night.

The feeding and resting postures of *S. irritans* are characteristically different. At rest in a cage, the flies sit with their heads downward, the wings almost flat along their backs and overlapping at the bases, the beaks nearly horizontal, and the legs not widely separated. On the host, they rest with their heads downward, with the wings somewhat spread (Riley, 1889a, b; Marlatt, 1910), and with no obvious orientation of the body to the lie of the hairs of the hide. Here again it

differs from *H. stimulans*, which rests superficially along the hairs, oriented along the hair streams, usually with the head upward (Hammer, 1942). When feeding, *S. irritans* burrows among the hairs, in the opposite direction to the lie of the hairs (Bruce, 1940, 1942; Hammer, 1942); the wings are slightly elevated and held out from the body at an angle of 60° to the abdomen (Riley, 1889a, b; Marlatt, 1910), the legs are spread widely, and the beak, held nearly perpendicular, is inserted into the hide (Bruce, 1940, 1942; Hammer, 1942). Herms (1939) states that, while feeding, *S. irritans* inserts and withdraws its proboscis repeatedly in the same puncture, in a pumping motion, and that engorgement requires 10 to 25 minutes. The flies are intermittent feeders (Bruce, 1942; Thomsen, 1938) and in the laboratory must be fed at least twice a day. An average meal consists of 1.71 milligrams of blood (Annand, 1941). The temperature of the natural environment of the flies is comparatively high, so that their metabolism and food requirements should be correspondingly high (Neveu-Lemaire, 1938; Thomsen, 1938).

Marlatt (1910) observed that the appearance and abundance of the flies were governed by temperature and rainfall. Pratt (1912) claimed that dry weather prevented horn fly development, whereas a series of showers caused a sudden and conspicuous increase in numbers. Hammer (1942) believed that the flies prefer a very high temperature and humidity, but that the range of preference is fairly narrow. When a large number of flies are collected from cattle and placed in a stoppered Erlenmeyer flask, a considerable amount of condensation forms on the inside, and the flies tend to cluster in a ball on the bottom of the flask; also, a single specimen will not live if kept alone in a large tube, death resulting presumably from desiccation (Hammer, 1942). At the Lethbridge laboratory, single flies kept in uncovered lantern chimney cages (at the relative humidity of the room, which varied from 40 to 60 per cent) and fed blood twice daily survived for a maximum of five days. When kept at a constant relative humidity of 90 per cent, they survived for a maximum of 12 days. Hammer (1942) believed that the condensation formed inside a flask when a large number of flies are present is due to evaporation from the flies and that the tendency of the flies to seek shaded and sheltered places on the host is to be regarded as a protection against too great evaporation and too high a temperature. Bruce (1940, 1942) stated that warm, damp, cloudy weather is the most favourable for horn fly development, whereas hot, dry weather or cold weather is unfavourable; he believed that, in general, temperature determines their presence and moisture their abundance. In southern Alberta it is unlikely that the weather during the summer would ever be hot enough to inhibit horn fly development; but we have frequently noticed that a few days of cold weather, either wet or dry (average temperatures of 5° to 10°C.) are followed by a great reduction in the numbers of horn flies on cattle.

In the laboratory, we have kept flies alive on artificial diets and on a calf for as long as 28 days. The survival of the fly in nature has been estimated at three weeks (Bruce, 1940), and at seven weeks (Bruce, 1942).

Out of 4,006 flies withdrawn at random from our rearing cages, 1,733 were males and 2,273 were females, a sex ratio of 1:1.3. Glaser (1924) found the sex ratio to be 1:1. Mohr (1943) found that 56 per cent of 225 reared individuals were females, a sex ratio of 1:1.2.

The mating habits of the horn fly have received little attention. Bruce (1940, 1942) states that mating has been observed as early as the second day after emergence. Hammer (1942) believes that prominent but protected objects,

such as a lonely bush, a cart, a stile, cows, or human beings, are the sites chosen for mating. Mating has not been reported to occur in cages in the laboratory. We have not yet seen the flies in the act of mating in nature in southern Alberta, but we have obtained evidence concerning when and where mating occurs.

In the newly emerged female there are no constrictions in the ovarioles and the oocytes cannot be distinguished from each other. When the constrictions appear and make the oocytes visible, the lowest oocytes in the ovarioles are about 0.1 mm. long. The ripe oocyte is 1.1 to 1.2 mm. long. The rate of ovary development varied in laboratory-reared flies that were confined in a screen cage on the back of a cow; at the end of three days the lowest oocytes in different flies were from 0.3 to 0.5 mm. long; at the end of four days they were 0.4 to 1.2 mm. long. The flies also mated in the cages, which had a volume of about 18 cubic inches, indicating that the flies are stenogamous. Females with sperm in the spermathecae were not found before the fifth day of confinement in the cages. Ten out of 16 females that had laid eggs in the cages had not mated. Early in the 1952 horn fly season (June 17), 30 wild female flies were dissected. Five of these had not deposited eggs. The reproductive system of one of the five was preserved and the spermathecae of the remaining four contained no sperm. In these four flies the ovaries were immature, the maximum length of the lowest oocytes was 0.3 mm., and the smallest were not yet constricted. These measurements indicated that the four unmated flies had been on the host not more than three days.

The only occasion on which the fly normally leaves the cow is to deposit its eggs. This usually occurs immediately the dung is passed, and the flies sometimes arrive at the droppings even before the cow has finished. Riley (1889a) observed that, as a cow began the act of passing the dung, 40 or 50 flies moved from the flank to the back of the thigh. At the close of the operation, these flies darted immediately to the fresh cake to deposit their eggs. We have observed that the response of the flies to the passing of the dung depends, at least in part, on where the flies are at the time. Regardless of the motion of the cow, the flies go directly to the cake if they are resting high on the cow when the dung is passed. But if the cow is standing still when the dung is passed and the flies are resting under the belly or low on the hind legs, the flies do not move toward the dung until the cow moves.

It is commonly stated that the eggs are laid "on" the droppings, suggesting that they are deposited on the upper surface of the cake. This was the only oviposition site observed by Riley (1889a). We have occasionally seen a few eggs deposited on the upper surface of the cake, but only on the drier type of dropping. On these rare occasions the eggs were tucked into a fold in the dung. As Bruce (1942) and Hammer (1942) have observed, the flies, on alighting on the fresh cake of dung, quickly spread over its surface and within one-half to three-quarters of a minute disappear under the sides of the cake. Within the next ten minutes the eggs are deposited one by one, usually in groups of four to six, under the sides of the cake or on the grass or soil beneath it. Mohr (1943) noted that the flies flutter as they move over the surface of the dropping.

In the eastern United States the eggs are laid during the warmer part of the day, between 9.00 a.m. and 4.00 p.m. (Riley, 1889a, b). Smith (1889, 1890) found the eggs but never observed the flies in the act of ovipositing, and concluded that the eggs were laid at night. In Illinois, Mohr (1943) observed that cattle commonly dropped dung about dusk, when drying is slow; if the evening was warm, small numbers oviposited at this time, but if cool they did not. In

B & Z LIBRARY

Denmark Hammer (1942) saw the flies on the freshly passed dung in the middle of the light nights of midsummer.

The specific stimuli that induce egg-laying are unknown. The freshly passed dung attracts the flies, but as noted above the attraction is not as spontaneous when air temperatures are comparatively high and the flies are under the belly of the cow or low on the hind legs. Hammer (1942) noted that formation of the crust reduces the amount of odour sent out by the dropping. This reduction in odour occurs rapidly, as soon as the surface of the dropping has assumed a dull lustre, which often happens within 15 minutes after the dung is passed. But Mohr (1943) found that, of all the insects attracted to cow dung, the horn fly was the only one not highly dependent upon the wind, and perhaps upon odour, for its direction of approach. He believes this is possibly because of its close presence at the time the dung is dropped, and conditioning to the movements of its host. Krijgsman and Windred (1933) found that *Lyperosia exigua* move against an air current, that they are attracted by the odour of the dung of the host, and that the attraction decreases as the dung ages.

When gravid females are placed in a jar with fresh dung many eggs are laid on the dung, but a large number of eggs are also laid on the wall of the jar. When a large number of gravid females are placed in a jar without dung, eggs are also laid on the wall of the jar. These observations suggest that high humidity may be the stimulus to egg deposition. During the summer the droppings are usually wet and when freshly passed have a temperature of about 37°C. Consequently the rate of evaporation from the droppings may be very high during the ten minutes in which the flies are on or under the cake depositing their eggs.

Glaser (1923) estimated that the preoviposition time was 17 days and Bruce (1940, 1942) three days. Glaser's flies were fed on artificial diets that very likely extended the preoviposition period. On the few occasions on which flies in the Lethbridge laboratory deposited eggs after feeding on artificial diets, the preoviposition periods were nine days for flies maintained at 29°C.±1°, 15 days for those at an average temperature of 21°C. (mean maximum 24°C., mean minimum 18°C.), 16 days for flies maintained at an average temperature of 21°C. (mean maximum 22°C., mean minimum 20°C.), and 20 days for flies maintained at an average temperature of 20°C. (mean maximum 23°C., mean minimum 18°C.). On the other hand, for flies newly emerged to three days old, egg laying began on the fifth day after the beginning of confinement in a screen cage on the back of a cow.

The maximum number of eggs found in a female at one time has been only 24 (Bruce, 1940), and Neveu-Lemaire (1938) states that about 20 eggs are laid at a time. Hearle (1938) states that less than two dozen eggs are laid during the life of each female, but Bruce (1942) estimates that a female is capable of laying 375 to 400 eggs. Each ovary usually contains 12 ovarioles, and the lowest oocytes in the ovarioles develop sychronously. We have seen wild females that had deposited one set of eggs and in which another set of oocytes had almost ripened, but some of the ovaries of these females contained as few as six developing ovarioles. We have also seen one laboratory-reared female in which two sets of oocytes had developed simultaneously, but this is probably an exception. In any event it seems certain that the female is capable of laying considerably more than two dozen eggs. Bruce's (1940, 1942) observations were made in the southern United States, where summer temperatures are high. Flies confined in cages on the back of a cow in southern Alberta in July did not begin to deposit eggs until five days later, and one specimen deposited two sets of eggs in eight days. The number of eggs that a female is capable of laying probably depends

on the optimum temperature and humidity for ovary development and on maximum longevity. Until those conditions are known, the potential egg production cannot be estimated accurately for the flies in any locality.

The Egg

The incubation period of the egg of *Siphona irritans* is less than 24 hours, even at room temperatures. Melvin and Beck (1931) and Melvin (1934) determined the incubation period at different constant temperatures. At 77°F. it averaged 19 hours and 39 minutes. As the temperature was increased the incubation period decreased until at 94°F. it averaged about 11 hours and 20 minutes. The eggs failed to hatch at 104°F. The observations of Larsen and Thomsen (1941) and Thomsen (1938) were generally in agreement with these. They found that the eggs would hatch at 38° to 39°C. but the larvae died very quickly; even at 35°C. there was a distinctly harmful effect. Bruce (1940) estimated the incubation period at 16 to 20 hours during warm summer days.

The eggs require a very high relative humidity. Larsen (1943a) found that only five per cent of the eggs hatched at 23°C. and a relative humidity of 93 to 94 per cent. Only 50 per cent hatched at a relative humidity of 96.1 per cent. No eggs hatched below 95 per cent relative humidity at temperatures of 32° and 33°C.

The Larva

The nature of the habitat is important to the survival and development of horn fly larvae. They live only in cattle dung, but the physical nature and composition of the dung varies greatly with the diet of the host and with time, and the diet of cattle on pasture or range varies with the season. The only observations on the nature and composition of cow dung in regard to horn fly development have been those of Hammer (1942) and Mohr (1943).

Hammer (1942) studied the variations in temperature and moisture content of cattle droppings in a pasture in Denmark. He found that at the moment the dung of cattle is passed it has a temperature of about 37.5°C. The fall in temperature within the dung varies with time and with the type of day. On warm (21° to 23°C.), sunny days the temperature within freshly passed dung falls by five to seven Centigrade degrees in the first hour. Under cooler air conditions the temperature falls more rapidly. After the insulating crust has formed, the temperature within the dropping may rise slightly. But after the dung has cooled it follows the temperature rhythm of day and night. The temperature conditions on the surface of the ground below the dung are similar to those at the bottom of the dung. In general, during the summer months, the average temperatures in the droppings, just under the crust, are considerably higher than those of the surrounding air and often rise over 30°C. Lower in the droppings, temperatures vary more slowly and do not reach the extremes of the air temperature. The water content of freshly passed dung is very high (79 to 89 per cent; dung that appears to be very dry contains 70 to 75 per cent). The water content varies, depending upon the diet of the cow, but there is also a difference within the 24 hours of the day. Dung dropped when the cows rise, after having rested most of the night, is less watery than dung dropped later in the day. Wet dung, dropped when cows are standing still, is shaped as a thick round cake with the middle portion only about two-thirds as thick as the edges. A pool of water accumulates on the surface of such a dropping in rainy weather because the surface becomes somewhat waterproof as it dries. When the droppings are thin they also have a depression in the middle. Eggs and larvae generally perish in long, thin, watery droppings that dry out quickly. In southern

Alberta, cattle dung tends to be drier and the cakes do not always form with a depression; instead they often have an elevation on the centre of the upper surface. Mohr (1943) found that, notwithstanding variations in water content and drying conditions, all droppings showed similar changes in colour and consistency. He describes the successive stages as: gleaming wet and greenish-brown, freshly passed; greenish-brown with distinct tarnish and film; uniformly brown and moist; blackish-brown with moist depressions; brown with distinctly dry crust; light brown with very thick crust; light brown chip, dry throughout. The first three or four changes occur fairly quickly, usually within the first day, so that the eggs of the horn fly are laid and hatch during those changes. Most of the larval development occurs while the cake is covered with a crust.

Cattle dung undoubtedly contains large numbers of microorganisms, and a rich supply of the proteins, carbohydrates, minerals (Dukes, 1947; Harrow, 1946), and accessory food substances required for insect growth and development. Little specific information is available on these constituents of the fresh droppings, but the kinds and quantities present undoubtedly depend on the diet of the cattle.

Many other insects occur in the droppings with the larvae of horn flies. Howard (1901) listed 25 species of Diptera; Pratt (1912), 31 species of Diptera, 17 of Coleoptera, and one of Lepidoptera. Hammer (1942) found 64 species of flies, representing 17 families, associated with cattle and their droppings and gave references to the findings of others. Mohr (1943) listed 83 species of arthropods representing five orders and 26 families found in and on droppings in open pastures in Illinois; the species found depended on the environment in which the droppings were found. The species occurred in succession and the horn fly, being an obligatory breeder in cattle dung, was first to appear on the droppings and its larvae were first to complete their development within the droppings. The associated insects, by their activities, modify the physical nature of the environment, producing tunnels or burrows and competing for the food (Hammer, 1942). Mohr (1943) cited the instance of the scarabaeid *Pinotus carolinus* (L.), which, in a single night, can remove so much of a dropping that the larvae of flies left behind starve or die beneath an inedible crust. In Puerto Rico, Wolcott (1924) found that during the dry season the small dung beetles *Aphodius lividus* (Oliv.) and *Ataenius stercorator* (Fab.) abound and eat all the fresh cow dung so that the horn fly larvae can hardly live. In the State of Apure, Venezuela, horn flies are much less numerous on cattle in woods or thickets because the droppings are immediately destroyed by the dung beetles that abound there. On the grassy plains, or llanos, these beetles are rare (Fiasson, 1943).

The larvae enter the dung as they hatch. They remain near the surface of the cake until ready to pupate, then move to the bottom (Riley, 1889a, b). According to Hammer (1942), the first-instar larvae apparently have cutaneous respiration and live in the liquid medium. In the second and third instars, they respire through the posterior spiracles and live in the air spaces and beetle tunnels under the crust.

Larsen (1943b) found the lower threshold of development of the larvae to be 12.9°C., the optimum temperature 32.3°C., and the upper limit of development 36°C., and that the larvae were killed within half a minute at 50° to 51°C. Thomsen and Thomsen (1937) found that third-instar larvae preferred temperatures between 27° and 33°C.; their experiments suggest that much lower temperatures are preferred just before pupation. Larval developmental time depends on the temperature and some of the reported observations are summarized

TABLE I

Duration of the Larval and Pupal Stages of *Siphona irritans*

Temperature conditions	Duration, days		Author
	Larva	Pupa	
18.2°C.	12.75	14.25	Larsen and Thomsen (1941)
18.6°C.	10.87	13.92	Larsen and Thomsen (1941)
24.4°C.	5.83	7.09	Larsen and Thomsen (1941)
25°C.	7		Thomsen and Thomsen (1937)
25°C.	6–8	5–7	Present study
29°C.	4–5		Present study
31.7°C.	3.71	3.96	Larsen and Thomsen (1941)
32.3°C.	3.71	3.83	Larsen and Thomsen (1941)
Room	4+		Mohr (1943)
Summer		4–5	Bruce (1940), Fletcher (1892)
Summer	4–6	5–8	Haseman (1927)
Midsummer		5	Winn (1893)
Summer	approx. 5		Bruce (1940), Neveu-Lemaire (1938)
Summer	approx. 7		Winn (1893)

in Table I. We found that it usually required about three days for all larvae in a batch to complete puparium formation at 25°C.

Bruce (1939) observed that the larvae preferred to pupate in soil containing 3.5 to 5 per cent moisture by weight. But the environment of the fully grown larvae must have a high relative humidity. Larsen (1943a) found that death of fully grown larvae occurred at 25°C. when the relative humidity fell below 96 per cent. But 100 per cent relative humidity was less favourable than a little lower, pupation being slower and mortality greater at 100 per cent.

The Pupa

The pupae require a drier environment than the larvae. The location where pupation takes place depends on the moisture content and type of soil beneath the droppings. From observations in the eastern United States, Riley (1889a) stated that pupation takes place either on the surface of the ground beneath the droppings or three-quarters of an inch below the surface of the ground, depending on the texture of the soil. Later (1889b), he stated that the puparium is formed in the ground beneath the dung. Mohr (1943), in Illinois, cited Riley's (1889a) statement and accepted it as the common habit, but noted that he reared several dozen that had pupated in the dropping. Hammer (1942), in Denmark, found the pupae more often in the ground beneath the droppings than in the droppings. Neveu-Lemaire (1938) stated that the pupae are found in the ground beneath the droppings at a depth of three to five centimetres. In the southeastern United States, Bruce and Blakeslee (1948) found that pupation takes place in the droppings or in the soil underneath. In the foothills of southern Alberta overwintering pupae and larvae are found within the droppings, on the surface of the ground beneath the droppings, and in the soil beneath the droppings. During the winter of 1949-50, 167 cattle droppings from a pasture were examined; the cattle had been removed from this pasture two days before the first killing frost of the autumn. Only 55 of the droppings, or the soil beneath, were found to contain horn fly larvae or pupae. From these 55 samples, 238 specimens were found in the droppings, 54 on the surface of the ground beneath the droppings, and 11 within the first half inch of soil beneath the droppings.[4]

[4]These collections and observations were made by Mr. W. A. Nelson and Mr. W. G. Godlonton of the Lethbridge laboratory.

Buxton (1936) found that the relative humidity of the air in the pores of soil depends not only on the moisture content of the soil but also on the type of soil. The atmospheric humidity was about 20 per cent in a sandy soil containing about 0.25 per cent moisture. The same soil, containing about 0.6 per cent moisture, had an atmospheric humidity of about 90 per cent. On the other hand, a soil with a large proportion of silt, clay, and organic matter had an atmospheric humidity of about 30 per cent when the moisture content was about 1.5 per cent, and an atmospheric humidity of about 90 per cent when the moisture content was about four per cent. In other words, the atmospheric humidity may be very high in soils with a low moisture content. Bruce (1939) found that development of horn fly pupae was inhibited in sand containing less than 0.25 per cent and more than 14.5 per cent moisture, maximum emergence occurring in sand with approximately seven per cent moisture. But, in the laboratory at 25°C., Larsen (1943a) found that all young horn fly pupae were killed very early in her experiments at relative humidities of 75 per cent and lower, no flies emerged from puparia held at relative humidities from 0 to 83 per cent, flies emerged in only one case at a relative humidity of 93 per cent, and there was a small delay in emergence at 100 per cent. From this, it appears that the young pupae require a relative humidity between 94 and 99 per cent.

According to Pierce (1921), when the larvae are ready to pupate they emigrate from the dung, and the puparia are usually found some distance away or under the sides of the manure cake. This observation seems to refer to the habits of *Haematobia stimulans* as given by European workers.

Under summer conditions, the time from formation of the puparium to emergence of the fly varies with the temperature. Some of the records from the literature are given in Table I. Emergence of the flies from the same batch of puparia may extend over several days. The females begin to emerge first, followed a day or two later by the first males. Bruce and Blakeslee (1948) stated that 99 per cent of the flies emerge from the puparia in the afternoon.

Overwintering

The overwintering habits of the horn fly vary with the geographic region. In tropical and semitropical regions, such as the Hawaiian Islands (Marlatt, 1910) and the southern United States (Bruce, 1940), the flies are said to continue to breed throughout the winter months. In the vicinity of Washington, D.C., and in New Jersey, the horn fly overwinters either in the adult or in the pupal stage (Marlatt, 1910; Smith, 1890). In colder regions, it overwinters in the pupal stage (Bruce, 1940; Fletcher, 1892; Hammer, 1942; Mohr, 1943; Winn, 1893).

In southern Alberta we obtained evidence that the third-instar larvae, as well as the pupae, may overwinter. Forty-six third-instar larvae were obtained from the 55 droppings mentioned above that were collected and examined from October, 1949, to June, 1950. Between October 5 and May 13, 32 of the larvae (the last two larvae were found on May 13) were placed on moist earth or in fresh cow dung at temperatures from 20° to 32°C.; nine of these larvae pupated and one fly emerged. Third-instar larvae are very likely able to survive the winter if, at the beginning of cold weather, they have reached the point where feeding has stopped preparatory to puparium formation. Young larvae were not found in the 167 droppings examined, and Mohr (1943) did not find horn fly larvae or pupae in dung dropped shortly before the first killing frosts.

The only references to a diapause in the life-cycle of the horn fly are those made by Larsen and Thomsen (1941) and Hammer (1942). Larsen and Thomsen (1941) found an arrest in development in the pupal stage in some of their cultures.

They suggest that the arrest is caused by a drop in temperature to 16° or 17°C., or that it is obligate, either after a cerain number of generations or seasonally. Hammer (1942) noticed that not all the individuals of a brood stopped development. Some of our observations also indicate that the overwintering pupae may be in diapause. Our laboratory flies were reared at or above 20°C., but development was slower and more erratic in pupae reared from eggs obtained after the end of August. On September 18, 1951, wild flies were collected at Lethbridge and their eggs were laid on the same day. These eggs were placed on fresh cattle dung and they hatched on the following day. By September 28 all the larvae had pupated. From these puparia, 1,103 flies emerged between October 6 and 10. But there were 150 puparia that by October 16 had not produced flies. On this date, the 150 puparia were placed in a room at -5°C., and left there for 16 days. On November 1 they were placed at room temperature. Two flies emerged on December 10, 40 days later, and during the following two months 86 flies emerged with never more than 12 flies emerging on any one day. From November 1 to March 11, the temperature conditions in the laboratory were as follows: mean maximum, 24.3°C.; mean minimum, 20.8°C.; and average mean, 22.6°C. These observations indicate that, if a diapause is involved in the life-cycle, low temperature cannot be the only cause, but low temperature may be involved in breaking the diapause.

Summary

The available literature on the life-history and habits of the horn fly, *Siphona irritans* (L.), is reviewed, and observations made in the laboratory and in southern Alberta are included.

The adult horn fly is an obligate parasite of cattle that remains on its host night and day. It leaves the host only to deposit its eggs, an operation that requires ten minutes at most. The fly is introduced to new regions only in the company of its host. It is generally considered a serious pest where it occurs but has not been implicated as a vector of disease organisms. The fly appears to prefer very high temperatures and humidities; these govern its resting, feeding, and egg-laying habits, its longevity, and the number of eggs laid; little is known about these preferences.

The flies are stenogamous. The available evidence indicates that mating takes place on the host and within three days after the flies reach the host. Mating is not a prerequisite for ovary development and egg-laying.

The eggs require a relative humidity near 100 per cent and hatch in less than 24 hours between 77° and 94°F.

The larvae live only in cattle dung and the nature of the habitat is important in their survival and development, but the physical, chemical, and biological conditions of the freshly passed dung have received little attention. The temperature range of development for the larvae is 13° to 36°C., with the optimum near 32°C. The larvae require a relative humidity just below 100 per cent.

Pupation is reported to occur in the droppings, on the surface of the soil beneath the droppings, or as deep as five centimetres in the soil beneath the droppings. Young pupae appear to require a relative humidity between 94 and 99 per cent. The duration of the pupal stage is reported as 3.8 days at 32.3°C. and 14.2 days at 18.2°C. The females begin to emerge first.

The horn fly is reported to undergo a diapause in the pupal stage in Denmark and southern Alberta. But its nature and the causes of its beginning and end are unknown.

Acknowledgments

It is a pleasure to record our indebtedness to Mr. N. E. Kloppenborg, Canada Experimental Station, Lethbridge, for a translation of the section dealing with horn flies in the paper by Thomsen (1938). Mr. Marvin Qually, of the Lethbridge laboratory, assisted with collections of flies and field observations.

References

Annand, P. N. 1941. Report of the Chief of the Bureau of Entomology and Plant Quarantine, 1941. U.S. Dept. Agr., Washington.

Bax, S. N. 1937. The senses of smell and sight in *Glossina swynnertoni*. *Bull. Ent. Res.* 28: 539-586.

Bezzi, M. 1907. Mosche ematofaghe. *Rendic. Istit. Lomb. Milano* 40: 433-460.

Bezzi, M. 1911. Etudes systématiques sur les muscides hématophages du genre *Lyperosia*. *Arch. Parasit.* 15: 110-143.

Bruce, W. G. 1938. A practical trap for the control of horn flies on cattle. *J. Kansas Ent. Soc.* 11: 88-93.

Bruce, W. G. 1939. Some observations on insect edaphology. *J. Kansas Ent. Soc.* 12: 91-93.

Bruce, W. G. 1940. The horn fly and its control. *U.S.D.A. Leaflet* 205.

Bruce, W. G. 1942. The horn fly. *In* Keeping livestock healthy, ed. by G. Hambidge, pp 626-630. U.S. Dept. Agr. Yearbook of Agriculture, Washington, D.C.

Bruce, W. G., and E. B. Blakeslee. 1948. Factors affecting tests with DDT sprays to control horn flies (*Siphona irritans*). *J. Econ. Ent.* 41: 39-42.

Bruce, W. G., and C. Eagleson. 1938. A new method of feeding adult horn flies, *Haematobia irritans L.*, and stable flies, *Stomoxys calcitrans* L. *J. Kansas Ent. Soc.* 11: 144-145.

Buxton, P. A. 1936. Studies on soils in relation to the biology of *Glossina submorsitans* and *tachinoides* in the north of Nigeria. *Bull. Ent. Res.* 27: 281-286.

Dukes, H. H. 1947. The physiology of domestic animals. 6th ed. Comstock Publishing Co. Inc., Ithaca, New York.

Fiasson, R. 1943. Notes sur les parasites animaux du Haut-Apure (Venezuela). *Rev. Sci. méd. pharm. vét. Brazzaville* 2: 125-151.

Fletcher, J. 1892. The cattle horn-fly (*Haematobia serrata*, Robineau-Desvoidy). *Canada Dept. Agr. Bull.* 14.

Glaser, R. W. 1923. The effect of food on longevity and reproduction in flies. *J. Expt. Zool.* 38: 383-412.

Glaser, R. W. 1924. Rearing flies for experimental purposes with biological notes. *J. Econ. Ent.* 17: 486-497.

Grünberg, K. 1906. Ueber blutsaugende Musciden. *Zool. Anzeig.* 30: 78-93. Cited by Bezzi (1911).

Hammer, O.1942. Biological and ecological investigations on flies associated with pasturing cattle and their excrement. *Vidensk. Medd. Dansk. naturf. For. København* 105: 141-393.

Harrow, B. 1946. Textbook of biochemistry, 4th ed. W.B. Saunders Co., Philadelphia.

Haseman, L. 1927. Controlling horn and stable flies. *Univ. Missouri Agr. Expt. Sta. Bull.* 254.

Hearle, E. 1938. Insects and allied parasites injurious to livestock and poultry in Canada. *Canada Dept. Agr. Pub.* 604.

Herms, W. B. 1939. Medical entomology. 3rd ed. The Macmillan Co., New York.

Howard, L. O. 1901. On some Diptera bred from cow-manure. *Canadian Ent.* 33: 42-44.

Jack, R. W. 1917. Natural transmission of trypanosomiasis (*T. pecorum* group) in the absence of tsetse-fly. *Bull. Ent. Res.* 8: 35-41.

Krijgsman, B. J., and G. L. Windred. 1933. Investigations on the buffalo fly, *Lyperosia exigua* de Meij. *Australia Coun. Sci. Ind. Res. Pam.* 43.

Larsen, E. B. 1943a. The influence of humidity on life and development of insects. Experiments on flies. *Vidensk. Medd. Dansk natur. For. København.* 107: 127-184.

Larsen, E. B. 1943b. Problems of heat death and heat injury. Experiments on some species of Diptera. *Vidensk. Selsk. Biol. Medd.* 19: 1-52.

Larsen, E. B., and M. Thomsen. 1941. The influence of temperature on the development of some species of Diptera. *Vidensk. Medd. Dansk naturf. For. København* 104: 1-75.

MacNay, C. G. 1952. Summary of the more important insect infestations and occurrences in Canada in 1951. *82nd Ann. Rept. Ent. Soc. Ontario*, 1951, pp. 91-115.

Marlatt, C. L. 1910. The horn fly (*Haematobia serrata* Rob.-Desv.). *U.S. Dept. Agr. Bur. Ent. Circ.* 115.

Melvin, R. 1934. Incubation period of eggs of certain muscoid flies at different constant temperatures. *Ann. Ent. Soc. Am.* 27: 406-410.

Melvin, R., and D. E. Beck. 1931. Length of the developmental stages of the horn fly, *Haematobia irritans* (Linne), at constant temperature. *J. Econ. Ent.* 24: 330-331.
Mohr, C. O. 1943. Cattle droppings as ecological units. *Ecol. Monogr.* 13: 275-298.
Morris, H. 1918. Blood-sucking insects as transmitters of anthrax or charbon. *Louisiana Agr. Expt. Sta. Bull.* 163. Reviewed in *Rev. Appl. Ent., B,* 6: 181. 1918.
Myers, J. G. 1938. Report on the natural enemies in Haiti of the horn-fly (*Lyperosia irritans*) and the green tomato bug (*Nezara viridula*). *J. Coun. Sci. Ind. Res.* (Australia) 11: 35-46.
Neveu-Lemaire, M. 1938. Traité d'entomologie médicale et vétérinaire. Vigot Frères, Paris.
Pierce, W. D. 1921. Sanitary entomology. Richard G. Badger, Boston.
Pratt, F. C. 1912. Insects bred from cow manure. *Canadian Ent.* 44: 180-184.
Riley, C. V. 1889a. The horn fly (*Haematobia serrata* Robineau-Desvoidy). *Ins. Life* 2: 93-103.
Riley, C. V. 1889b. Report of the Entomologist. *In* First report of the Secretary of Agriculture, 1889, pp. 331-361. U.S. Dept. Agr., Washington.
Smith, J. B. 1889. The horn fly (*Haematobia serrata*). *New Jersey Agr. Expt. Sta. Bull.* 62.
Smith, J. B. 1890. Notes on the structure and history of *Haematobia serrata*. *Psyche* 5: 343-347.
Thompson, H. J., D. M. Worstell, and S. Brody. 1951. Environmental physiology with special reference to domestic animals. XV. Influence of environmental temperature, 0° to 105°F., on hair and skin temperatures and on the partition of heat dissipation between evaporative and non-evaporative cooling in Jersey and Holstein cattle. *Univ. Missouri Agr. Expt. Sta. Res. Bull.* 481.
Thomsen, E., and M. Thomsen. 1937. Uber das Thermopräferendum der Larven einiger Fliegenarten. *Z. vergl. Physiol.* 24: 343-380.
Thomsen, M. 1938. Stuefluen (*Musca domestica*) og Stikfluen (*Stomoxys calcitrans*). Undersøgelser over Biologi og Bekaempelse samt en Oversigt over andre til Husdyr eller Boliger Knyttede Fluearter. *Beretn. Vet.-og Landbohøjsk. Forsogslab. No.* 176.
Wilhelmi, J. 1917. Zur Biologie der kleinen Stechfliege, *Lyperosiâ irritans* (L.). *SB. Ges. naturf. Freunde Berlin* 1917: 510-516.
Winn, A. F. 1893. The horn fly (*Haematobia serrata*, Robineau Desvoidy). *Canadian Rec. Sci.* 5: 272-275.
Wolcott, G. N. 1924. Entomologia Economica Puertorriguéna. *Puerto Rico Dept. Agr. Trabajo, Estac. Exp. Insular, Rio Piedras, Bol.* 32. Cited by Myers (1938).

(Received April 28, 1953)

A Plastic Cage for Rearing Small Parasites[1]

By A. P. ARTHUR[2]
Laboratory of Entomology, Belleville, Ontario

The biologies of *Zagrammosoma americanum* Gir. and other small chalcid parasites are being studied at the Belleville laboratory. During these investigations a cage was required that would: (1) permit microscopic observation, with a minimum of disturbance to the insect, (2) allow ready introduction and removal of food and host material, without danger of the insects escaping, and (3) have aeration holes through which the interior could be sprayed. The description of a cage that satisfies the above requirements follows.

The cage (Fig. 1,A) is made of plastic (Lucite[3]) approximately 1/16 in. thick.

The parts are cut out (Fig. 1,B) and assembled in the following manner, with ethylene dichloride as a solvent. The parts for a number of cages may be cut at one time from scraps available in most laboratory workshops.

Strips of silk bolting cloth are cemented over the three holes in each of the side pieces, the solvent being applied with an eye dropper. A second application of the solvent is usually necessary. Strips of plastic ⅛ in. wide are cemented to the end and side pieces approximately 1/32 in. from what eventually will be the

1Contribution No. 3084, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.
2Agricultural Research Officer.
3A plastic product of Johnston Industrial Plastics Limited, Toronto, Ontario.

inside bottom edge. The sides, end, and top are then glued to the bottom in that order to form a frontless box. The bottom protrudes ⅛ in. in front of the body of the cage. Two strips of plastic are glued together at right angles as shown in Fig. 1,B, top left. Two such angles are made. Each angle is glued

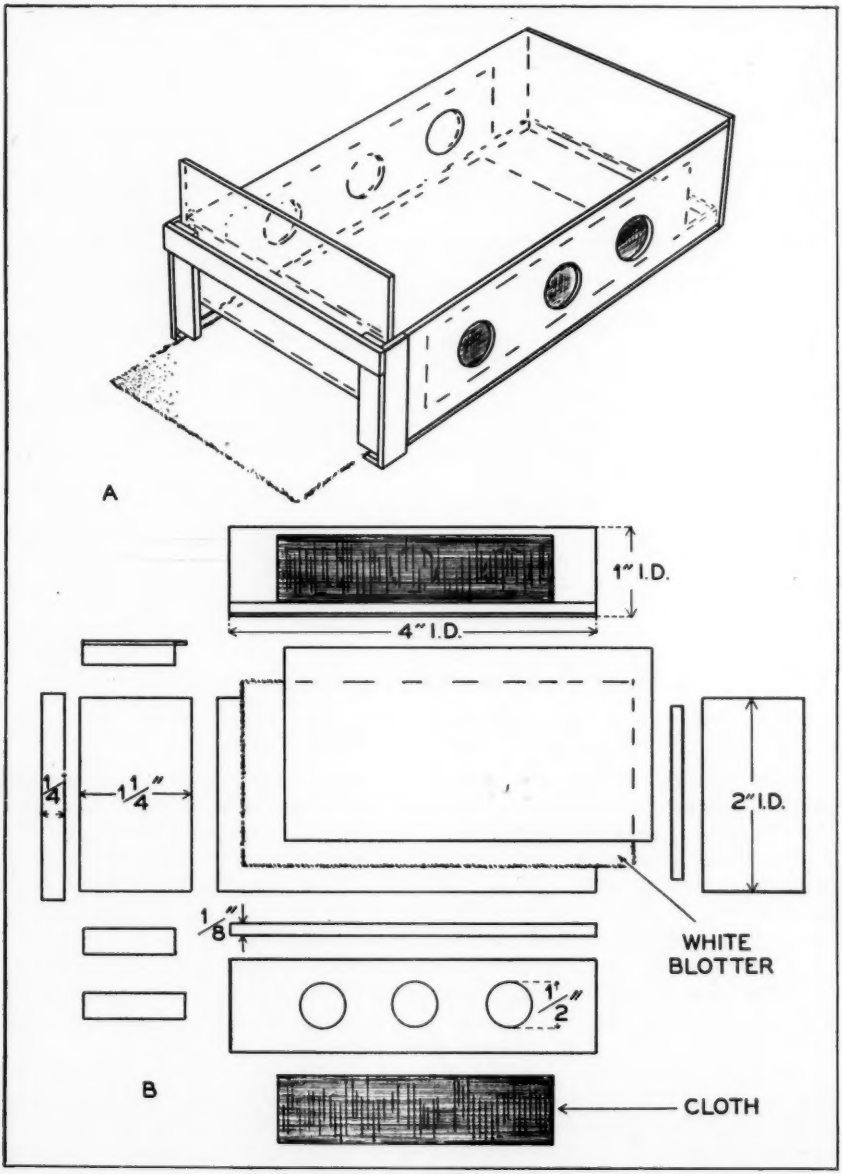


Fig. 1. A, Cage for rearing small parasites assembled and ready for use. B, Component parts of the cage.

to the side of the cage, the shorter strip protruding beyond the front, ⅛ in. from the ends of the sides and parallel to them. A sliding front is fitted into the groove thus formed. A narrow strip of plastic is glued to the end-pieces parallel to the top of the cage to provide greater rigidity. More solvent is applied to all points after the cage is assembled. A piece of white blotting paper, cut to fit, is slid into the cage along the bottom. The edges of the blotting paper are held in place both by the strips of plastic on the inside of the cage and by the sliding front.

There are several advantages in using this type of cage. Its small size and compactness render it particularly suitable for housing one or a pair of chalcid parasites. Furthermore, light may enter the cage from any direction except the bottom. With a cage of this size and transparency the insects can be viewed through a binocular microscope without removing them from the cage. Because no extra light enters the cage when the sliding front is opened, the parasites are not unduly disturbed and hence rarely escape. They may be sprayed with water through the aeration holes in the sides. The cage, with only slight modifications, would undoubtedly prove useful for the laboratory rearing of many other small insects.

The author acknowledges the technical advice and assistance of Mr. T. H. Stovell and Miss D. Wadsworth.

(Received April 29, 1953)

Descriptions of Larvae of Forest Insects: *Syngrapha*, *Autographa* (Lepidoptera: Phalaenidae)[1]

By W. C. McGuffin[2]

Introduction

The larvae of the plusiine genera *Syngrapha* and *Autographa* have but two pairs of ventral abdominal legs; typical phalaenid larvae have four pairs of these legs. The setal arrangement seems to be fairly constant. Intraspecific variation in setal positions seems to be as great as interspecific. The patterns on the head (Figs. 2 and 3), thorax (Figs. 1, 6) and abdominal segments two and six (Fig. 6) are illustrated. The setal classification of Hinton (3) has been used here.

Five species of the genus *Syngrapha* (*S. selecta* Wlk., *S. alias* Ottol., *S. celsa* Hy. Edw. and *S. epigaea* Grt.) and one of *Autographa* (A. *ampla* Wlk.) have been studied. A key to the species of larvae has been included for the convenience of other workers.

The nomenclature used throughout the paper is that of McDunnough in his revision of the Plusiinae (6).

Acknowledgments

The encouragement and advice given by Mr. G. R. Hopping, Officer-in-Charge of the Calgary Forest Zoology Laboratory while this paper was in preparation has been greatly appreciated. To Dr. D. A. Ross, of the Forest Insect Laboratory, Vernon, British Columbia, the writer is grateful for the loan of larvae and notes on the species, *S. celsa* Hy. Edw.

Syngrapha selecta Wlk.

In an earlier description of this larva (2) there was some confusion of the species: *selecta*, *alias*, and *rectangula*; the first two, *selecta* and *alias*, can now be separated quite readily. The species, *S. rectangula*, has not been studied. If it differs from the closely-related *S. alias*, the difference will likely be found in a study of colour pattern. The larva illustrated in the paper by Brown and McGuffin (2) is of the species *S. selecta*.

(Description of one larva, Forest Insect Survey, record no. 50, Alberta, 361A, collected by P. F. LaRue from white spruce near Ft. Assiniboine, Alberta, on June 13, 1950. This larvae was described on June 19, it pupated June 30, and emerged as a male on July 20).

Ultimate Instar. – Head width 2.0 mm. Body 25 mm. in length and 4 mm. in width. Integument of body tomentose. Ground colour of body green; middorsal line dark green; addorsal line white, then a green line bearing setae D1 and D2 along its lateral edge. Subdorsal is fine white line. Supraspiracular stripe green. Lower edge of supraspiracular stripe greyed. Spiracular line yellow. Venter pale green. Integument of head smooth. Head pale green, with brown herring-bone pattern on upper part of epicrania. Setae long, dark brown, pointed; dorsal setae surrounded by small black spots. Spiracles hyaline with narrow light brown rims. Thoracic legs and abdominal legs green.

Variations in size and colour as determined by a study of 12 larvae are: Head width of antepenultimate instar, 1.33 mm., of penultimate instar 1.75 to 1.90 mm. and of ultimate instar, 2.28 to 2.53 mm. Bodies of penultimate instar larvae 10 to 11 mm. in length and of ultimate instar larvae 12 to 29 mm. in length. Epicranial index of the last two instars varies from 1.00 to 1.36. Crochets of ventral abdominal legs number from 22 to 36.

[1]Contribution No. 101, Division of Forest Biology, Science Service, Department of Agriculture, Ottawa, Canada.

[2]Agricultural Research Officer, Forest Zoology Laboratory, Calgary, Alberta.

The larvae of this species, which is transcontinental in distribution, feed on black and white spruce, balsam fir, Douglas fir, white and lodgepole pine, and tamarack.

***Syngrapha alias* Ottol.**

Ultimate Instar. – (Twenty larvae studied). Head width 1.90 to 2.28 mm. Body 12 to 25 mm. in length and about 4 mm. in width. Integument of body tomentose. Colour of body much as in *S. selecta* but spiracular line white (yellow in *S. selecta*). Venter green. Integument of head smooth, pale russet-green with brown freckles on epicrania. Setae long, brown, pointed. Spiracles oblong-oval in shape with yellow centres and fine, brown rims.

Epicranial index 1.17 to 1.31. Crochets of ventral abdominal legs number 20 to 30.

This species is transcontinental in distribution (6). Food plants of the larvae are various species of spruce, fir, and larch.

One parasitized larva, doubtfully identified as *S. rectangula* Kby. was seen on loan from the Forest Insect Laboratory at Vernon, B.C. In colour and setal arrangement the specimen was much like larvae of *S. alias*. Head width 1.52 mm; length of body 12mm. Crochets on ventral abdominal legs numbered 23 to 24; epicranial index 1.33mm. J. Clark, a worker in the Forest Insect Laboratory at Fredericton, New Brunswick, has separated the species *S. rectangula* and *S. alias* on the basis of frass pellets. He found that in *S. rectangula* the pellets were dark brown to black, cylindrical in shape and single; the finely masticated fragments had a relatively smooth surface. In *S. alias*, the pellets were mostly light brown; about one-third of these pellets were double and the coarsely masticated fragments had a rough surface.

***Syngrapha celsa* Hy. Edw.**

(Description of one larva preserved in alcohol, Forest Insect Survey, Record No. 51, Vernon 378, collected at Salmon River, near Prince George, British Columbia, from alpine fir in early June of 1951). Determination of this larva was made by P. A. Jones of the Forest Insect Laboratory, Vernon, British Columbia.

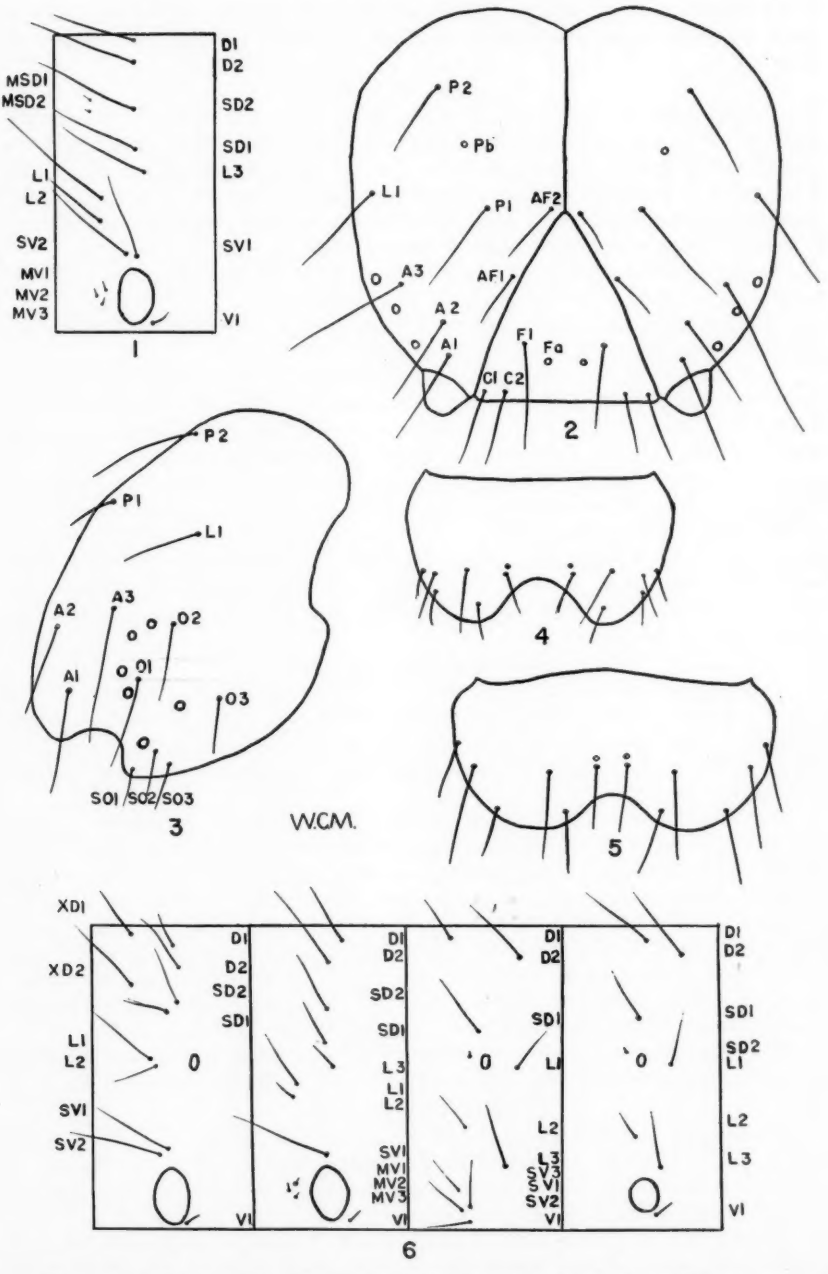
Ultimate Instar. – Head width 1.90mm. Body 12mm. in length and 2.2mm. in width. Integument of body tomentose. Ground colour of body green. Mid-dorsal stripe grey-green. Supraspiracular stripe grey-green. Spiracular stripe ground colour. Lower part of body pale grey-green. Integument of head smooth. Head green with brown herring-bone markings on epicrania. Setae long, brown, most setal bases surrounded by black circular areas. Spiracles with narrow pale-brown rims and yellow centres. Thoracic legs ground colour proximally and dark brown distally; claws black. Abdominal legs ground colour. Epicranial index 1.00. Crochets of ventral abdominal legs number 18.

The Canadian range of this insect is British Columbia and the southern part of Vancouver Island (4). The food plants are alpine fir and grand fir.

***Syngrapha epigaea* Grt.**

(Description of one larva, Forest Insect Survey, record No. 51, Alberta 1126A, collected by E. J. McNeil from trembling aspen near Rocky Mountain House, Alberta, on July 2, 1951. This larva was described on July 12; it pupated on July 21 and a male emerged July 31).

Ultimate Instar.–Head width 2.29 mm.; body 23 mm. in length and 4 mm. in width. Integument of body tomentose. Ground colour of body pale green. Mid-dorsal line ground colour. Addorsal line fine, white. Setae D1 and D2 are on a pale green line. Subdorsal line fine, broken white. Supraspiracular line ground colour. Spiracular line yellow. Below spiracular, body is ground colour. In-



Figs. 1-6. 1. Setal pattern of mesothorax of *Syngrapha alias* Ottol. 2. Frontal aspect of head of *S. selecta* Wlk. 3. Lateral aspect of head of *S. selecta* Wlk. 4. Labrum of *Autographa ampla* Wlk. 5. Labrum of *S. selecta* Wlk. 6. Setal patterns of prothorax, mesothorax, second and sixth abdominal segments of *S. selecta* Wlk. *All* figures drawn from mature larvae.

tegument of head smooth. Head pale green. (In the two other specimens seen there was a dark bar extending from the supraspiracular level on the prothorax to the ocellar region of the head). Prothoracic and anal shields ground colour. Setae long, pale brown. Spiracles pale brown with narrow brown rims. Legs ground colour; thoracic legs pale brown distally.

Variations in size as determined by a study of three larvae are: head width 2.00 to 2.66mm.; body 22 to 24mm. in length. Epicranial index 1.0. Crochets of ventral abdominal legs number 23 to 25.

According to McDunnough (6) this species is transcontinental in distribution. The larvae have been collected from juniper, blueberry, trembling aspen, spiraea, larch, and saskatoon.

Autographa ampla Wlk.

Ultimate Instar. — (Five larvae studied). Head width 2.00 to 2.28mm. Body 15 to 30 mm. in length and 3.5mm. in width. Integument of body smooth. Ground colour pale green. Middorsal line dark green. Addorsal line yellow green. Setae D1 and D2 on a pale green line. Subdorsal line broken, yellow. Supraspiracular stripe ground colour. Fine yellow line in spiracular region. Below this line body is pale green. Integument of head smooth; green in colour. Prothoracic and anal shields pale green. Epicranial index 1.20 to 1.50. Crochets of the ventral abdominal legs number 12 to 29.

This species is found throughout southern Alberta. It occurs as far north, at least, as Jasper National Park and Cold Lake. It has been reported also from southern British Columbia (4). The food plants are trembling aspen, alder, willow, white birch, balsam poplar and buffalo berry (*Shepherdia canadensis*). About one half the specimens received in the Calgary laboratory were from trembling aspen.

Key to Mature Larvae

1. Integument of body smooth, labral notch deep (Fig. 4) ..... *Autographa ampla*
   Integument tomentose; labral notch somewhat shallow (Fig. 5) ..... *Syngrapha* 2
2. One seta in SV position on mesothorax and metathorax (Fig. 6) 3
   Two setae in SV position on mesothorax and metathorax (Fig. 1) 4
3. Grey line above spiracles on abdomen; spiracular line pale yellow; no dark bar from ocellar area to posterior edge of head ..... *S. selecta*
   No grey line above spiracles on abdomen; spiracular line narrow, conspicuous; may have dark bar from ocellar area to posterior edge of head ..... *S. epigaea*
4. Circular brown or black spots around setal bases on abdomen large and conspicuous; ventral area of abdomen dark grey-green ..... *S. celsa*
   Circular brown spots around setal bases on abdomen small; ventral area of abdomen green ..... *S. alias*

References

1. Bowman, K. 1951. An annotated list of the Lepidoptera of Alberta. Can. Jour. Zool. 29: 21-165.
2. Brown, A. W. A. and W. C. McGuffin. 1942. New descriptions of larvae of forest insects. III *Zanclognatha, Palthis* and *Autographa* (Lepidoptera, Phalaenidae). *Can. Ent.* 74: 52-56.
3. Hinton, H. E. 1946. On the homology and nomenclature of the setae of the lepidopterous larvae, with some notes on the phylogeny of the Lepidoptera. Trans. R. Ent. Soc. Lond. 97, pt. 1: 1-37.
4. Jones, J. R. J. Llewellyn. 1951. An annotated list of the Macro-lepidoptera of British Columbia. Ent. Soc. B. C. Occas. Paper No. 1: 1-148.
5. McDunnough, J. H. 1938. Check List of the Lepidoptera of Canada and the United States of America. Pt. 1. Macrolepidoptera. Mem. S. Calif. Acad. Sc. Vol. 1: 1-272.
6. McDunnough, J. H. 1944. Revision of the North American genera and species of the phalaenid subfamily Plusiinae (Lepidoptera). Mem. S. Calif. Acad. Sc. Vol. 2, No. 2. 175-232.

(Received May 14, 1953)

Biology of *Agathis laticinctus* (Cress.) (Hymenoptera: Braconidae), A Parasite of the Eye-spotted Bud Moth, in Nova Scotia[1]

By C. D. DONDALE[2]
Fruit Insect Section, Science Service Laboratory
Kentville, Nova Scotia

Introduction

The eye-spotted bud moth, *Spilonota ocellana* (D. & S.), has been and continues to be an orchard pest of considerable economic importance in the temperate zone of North America. During the past seven years, observations have been made on the ecology of this insect in Nova Scotia. Among the biotic agents found attacking it is the hymenopterous parasite *Agathis laticinctus* (Cress.) [*Microdus ocellanae* Richardson].

Literature on *A. laticinctus* is scanty, consisting chiefly of host records. Authors reporting it as a parasite of the eye-spotted bud moth include Riley and Howard (1890), Slingerland (1893), DuPorte (1915, 1917), Sanders and Dustan (1919), Porter (1924), and Boyce (1949). A few host insects other than the eye-spotted bud moth are listed in the literature, but Muesebeck and Walkley (1951, p. 120) do not accept them.

Host larvae were collected in orchards from the time the young caterpillars established themselves on apple leaves in August until they became mature the following summer, in July. Larvae in all instars were dissected for internal parasites, and others reared to maturity for parasite emergence in individual vials. Representative adult parasites were determined by Dr. O. Peck, Dr. W. R. M. Mason, and Mr. G. S. Walley, Division of Entomology, Ottawa.

Description of Stages

The eggs of *A. laticinctus* are small and very inconspicuous. Only seven have been observed by the writer, and each was found closely attached to a ganglion of the host caterpillar ventral nerve chain (Fig. 1). One was attached to the first thoracic, another to the eighth abdominal, and the remainder to intervening ganglia. The egg varies in size according to the stage of incubation, and when near hatching is approximately twice as large as the ganglia. Just before hatching, the curled embryo may be removed by dissection. This is best done in physiological saline (0.75 per cent NaCl) under the high power of a binocular microscope (48X).

The newly hatched larva remains curled for a time, floating freely in the host haemocoel. It is mainly opaque, with some translucent areas. The body tapers somewhat sharply to a caudal vesicle, and most individuals possess a number of pairs of short, fleshy ventral processes on the trunk segments. The average body length and the head capsule width of 30 individuals were 0.75 mm. and 0.17 mm. respectively.

The overwintering larva, as found from late August to the following April, is more distinctive (Figs. 2-3, 6-7). Total body length averages 1 mm., and each thoracic and abdominal segment bears a pair of fleshy ventral processes, these being progressively larger toward the posterior end of the insect. Behind the eleventh segment is a characteristic, downward-curving, median caudal process, best seen from a lateral view (Fig. 6). The head is blunt, and the body no longer tapers but appears of nearly uniform width throughout (Fig. 7).

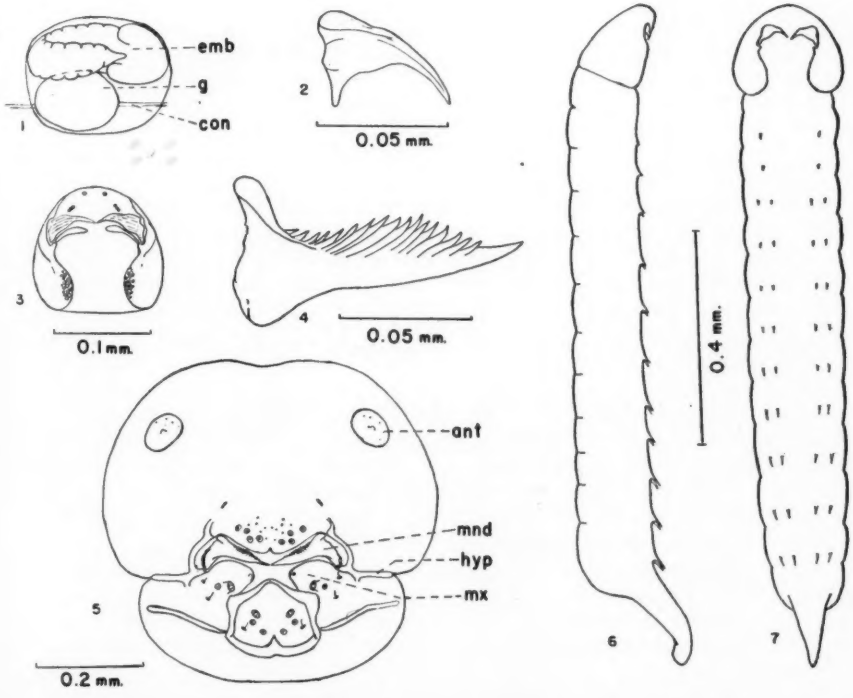
Growth is resumed in the spring some time after the host caterpillars emerge from hibernation and enter the buds. The parasite becomes progressively larger

1Contribution No. 3079, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.
2Technical Officer.

through a series of instars. Ingested food shows clearly the outline of the alimentary canal, until the growing fat body finally obscures it. The caudal process is much reduced in the second and succeeding instars.

When the host is mature and has "spun up", some time in late June or early July, *A. laticinctus* makes its exit by biting a hole in the pleural region of the thorax and wriggling free, the process requiring from one-half to two hours. The parasite then feeds externally and withdraws all fluids from the host's body, this bringing about collapse of the internal organs and death of the host. This final feeding requires from one to three hours. The parasite now displaces its host entirely, and rests for about five hours before spinning a cocoon inside the host's "spin-up". At this stage, the mouth parts are distinct (Figs. 4-5), tracheae and spiracles have appeared, and a yellowish, opaque fat body distends the whole organism. Paired, brownish, crescent-shaped areas in what appeared earlier as the first trunk segment, foreshadow the compound eyes of the adult. The mature larva measures 5 mm. in length.

In pupating, the parasite pushes the exoskeletal remnants of the host behind it. The cocoon is moderately rigid, white, and nearly elliptical; the lengths and widths of 30 individuals ranged from 5 to 6 mm. and 1 to 1.5 mm. respectively. An encircling band, whiter than the silk at the ends of the cocoon and about



Figs. 1-7. *Agathis laticinctus* (Cress.). 1. Egg on host ganglion (diagrammatic). emb, embryo; g, host ganglion; con, interganglionic connective. 2. Mandible of first-instar larva. 3. Head capsule of first-instar larva, ventral view. 4. Mandible of mature larva. 5. Face of mature larva. ant, antenna; mnd, mandible; hyp, hypostoma; mx, maxilla. 6. First-instar larva, lateral view. 7. First-instar larva, ventral view.

1 mm. wide, always occurs at the mid-section. Inside the cocoon, the parasite first exudes the larval meconium and later sheds the larval skin. The former, before discharge, appears as a caramel-coloured aggregate at the caudal extremity of the larva. It passes out of the body via the anus and both meconium and larval skin pass to the posterior end of the parasite cocoon, where they dry and gradually darken. The prepupal stage lasts for 36 to 48 hours, during which the body takes on the distinctive contour of the adult stage. The prepupal and pupal stages together required 10 to 14 days.

Thirty adults measured as follows: length, 3.9 to 4.9 mm.; ovipositor sheath of females, 3.3 to 4.1 mm., or about two-thirds of body length. The adults rest in such a way that the body makes roughly a 45° angle with the substratum. A detailed description is given by Muesebeck (1927).

Table I shows the cumulative percentages of adult parasites emerging by weekly intervals during the emergence period. The peak of emergence occurred during the latter two weeks of July except in 1950, when it occurred early in August.

TABLE I

NUMBERS OF *A. laticinctus* REARED AND PERCENTAGES OF TOTAL EMERGED BY WEEKLY INTERVALS

Year	Number reared	Percent emerged							
		July				August			
		7	14	21	28	4	11	18	25
1947	623	0	0.8	19.9	70.1	93.2	99.8	99.8	100.
1948	187	0	0	2.1	48.1	95.7	100.	—	—
1949	87	2.3	8.1	65.1	99.9	100.	—	—	—
1950	225	0	0	0.4	7.1	46.3	90.3	95.1	95.8

Sex Ratio and Reproductive Capacity

The ratio of males to females emerging in rearing boxes in the various years was slightly in favour of the males. Of 703 adults, 336, or 47.8 per cent, were females. Males and females began emerging at about the same date.

Preliminary data indicate that a single *A. laticinctus* female may parasitize as many as 15 to 20 hosts, laying one egg per host:—

Hosts exposed	46	76	16
Female parasites	3	3	4
Hosts parasitized	14	50	13
Average hosts parasitized per female	4.7	16.7	3.3

Habits of the Adults

The adults are able to survive for some time on liquid food. In the laboratory, they readily took up a 25 per cent cane sugar solution from a cotton plug in a vial and lived on it for a week or more. In the field, females were observed on the flowers of wild carrot, *Daucus carota* L., along with numerous

other parasitic Hymenoptera, apparently seeking food. The adult was not observed to feed on host caterpillars.

The act of mating was not observed, but unmated females laid eggs in bud moth caterpillars. In one instance, four unmated females laid eggs in 51 per cent of a group of 100 hosts.

Egg laying was observed on several occasions. The time of day was from noon to late afternoon, when the temperature was 70°F. or higher. Females were flying about the foliage of apple trees on which an abundance of early-instar caterpillars of the eye-spotted bud moth were feeding. The female flies from leaf to leaf and walks over both surfaces, continuously tapping with her antennae until she locates a web with a caterpillar inside it. She then raises her abdomen and inserts the tip of the ovipositor into the caterpillar. This position is maintained for about 12 seconds, after which she withdraws her ovipositor. Most females observed oviposited directly through webs, but one was seen to perform the act from the upper leaf surface by pushing her ovipositor through the leaf into the larva. Bud moth larvae just parasitized appear normal and sensitive to probing. In one case, the initial thrust of the female's ovipositor stimulated the caterpillar to emerge from its web. The parasite thereupon began to thrust repeatedly and rapidly, and then remained quiet for about 40 seconds before flying away. This caterpillar showed no response to probing and died without resuming feeding.

Instances where more than one individual of *A. laticinctus* occur in the same host are sometimes seen during dissections; in one such instance, 19 abnormally small individuals were found.

Life-Cycle

The adult parasites are present during the latter half of July and the first half of August. The eggs are laid during this time, and hatch probably within a week after being laid. By early September, all of the parasites have become polypodeiform larvae and entered hibernation, remaining in the first instar. The following May, the parasites resume activity and development, some within two weeks after the host enters the buds and others after a longer time. Because the parasite feeds slowly at first, and only on non-vital structures, the host caterpillar is able to attain full growth and to make its "spin-up". But at this stage the parasite feeds more rapidly and kills the host before pupation can take place.

Almost all unparasitized hosts will have pupated before the parasitized hosts die. This permits the unparasitized individuals time to become moths, and the moths to lay eggs, while the parasite is in late-larval and pupal stages. The result is that early-instar host caterpillars and adult parasites appear in the field at about the same time.

Natural Enemies

The parasite is itself attacked by a number of parasites and predators. A few first-instar larvae examined in 1952 contained one or two planidium-type hyperparasites, though none of these were reared. The mature larva is sometimes attacked by the ectoparasitic ichneumonid *Scambus hispae* (Harr.), which also attacks the mature larvae of the eye-spotted bud moth. Adults of this ichneumonid have been reared through a life-cycle on larvae of *A. laticinctus*. The adults of *A. laticinctus* are apparently readily caught by spiders, and the bodies of numerous individuals have been found in the webs of *Dictyna* spp., both on ground cover and on fruit trees. Two species of primary parasites have also been observed occasionally in the same host with *A. laticinctus*. These were in

some cases, a braconid, *Meteorus trachynotus* Vier., and in others an unidentified dipterous larva.

Summary

Agathis laticinctus (Cress.) is one of the biotic agents found attacking the eye-spotted bud moth in Nova Scotia. The parasite lays its eggs in the latter half of July and the first half of August, depositing them on the ganglia of the ventral nerve chain in larval hosts of the first and second instars. The eggs hatch within about one week, and the parasite floats freely in the host haemocoel. By early September all of the parasites have developed to the distinctive overwintering form.

Growth is resumed in the spring, some time after the host enters the buds. Feeding is slow at first, and only on non-vital structures, so that the host larva is able to become mature. A period of more rapid feeding is then followed by an exit from the host's body, a final period of feeding externally, and the host's death. Pupation takes place in the host's "spin-up". Adults began to appear 10 to 14 days after pupation, and reached a peak usually during the latter two weeks of July. The females laid eggs whether or not mating occurred.

Natural enemies of *A. laticinctus* include an ichneumonid, a braconid, a planidium-type hyperparasite, and a species of Diptera.

Acknowledgments

Thanks are due Messrs. H. T. Stultz and F. T. Lord, of the Kentville laboratory, for advice and guidance.

References

Boyce, H. R. [1949]. Natural enemies of the eye-spotted bud moth (*Spilonota ocellana* [D. & S.]). *30th Rept. Quebec Soc. Prot. Plants*, 1945-47, pp. 172-175.

DuPorte, E. M. 1915. Some insect parasites of the bud moth. *7th Ann. Rept. Quebec Soc. Prot. Plants*, 1914-15, pp. 76-77.

DuPorte, E. M. 1917. The eye-spotted bud moth. *9th Ann. Rept. Quebec Soc. Prot. Plants*, 1916-17, pp. 118-137.

Muesebeck, C. F. W. 1927. A revision of the parasitic wasps of the subfamily Braconinae occurring in America north of Mexico. *Proc. U.S. Nat. Mus.* 69(16): 22-73.

Muesebeck, C. F. W., and L. M. Walkley. 1951. Family Braconidae. *In* Hymenoptera of America north of Mexico. Synoptic catalogue, by C. F. W. Muesebeck, K. V. Krombein, and H. K. Townes, pp. 90-184. U.S. Dept. Agr., Agr. Monogr. 2.

Porter, B. A. 1924. The bud moth. *U.S.D.A. Bull.* 1273.

Riley, C. V., and L. O. Howard. 1890. Some of the bred parasitic Hymenoptera in the National Collection. *Insect Life* 3(1): 15-18.

Sanders, G. E., and A. G. Dustan. 1919. The apple bud-moths and their control in Nova Scotia. *Canada, Dept. Agr., Bull.* 16 (tech. ed.).

Slingerland, M. V. 1893. The bud moth. *Cornell Univ. Expt. Sta. Bull.* 50.

Two New Species of *Coccinellidae* (Coleoptera)[1]

By W. Y. Watson[2]

During the summer of 1948, the Royal Ontario Museum of Zoology and Palaeontology sent an expedition to the region of Cape Henrietta Maria on the north-west corner of James Bay, Ontario. Among the insects collected were specimens of two new species of Coccinellidae. Descriptions of these are given here.

Hippodamia parva n. sp.

Small, elongate, only slightly convex; black with reddish-orange elytra. Punctation fine and even on head, pronotum and elytra. Head with an ivory-white spot at the anterior mesal margin of each eye. Pronotum with narrow, white lateral margins extending only slightly along the anterior border. Elytra with three, large, black spots each (Fig. 1). Scutellar spot (½ + ½) joined with spot 3 on each side. Spots 1 and 2 lightly pigmented and small, 1 being somewhat larger. Spots 4 and 5 form an oblique fascia on each elytron, 5 being larger than 4. Spot 6 is large and almost round in the apical angle of each elytron. Underside black. Length: 4.4 mm.

Male Genitalia (Fig. 2-3): Sipho sharply bent, capsule inflation elongate, projections oblique. End of sipho beyond the flaps long and slender. Aedeagus slightly longer than paramera, wide near base, swollen to about ⅔ its length then quickly narrowing and produced in a long, narrow, blunt projection. Ventral alae narrow, angulate, produced but barely projecting below aedeagus. Paramera long and broad, acetabula nearly dorsal, basal plate longer than wide.

Female Genitalia (Fig. 4): Seminal receptacle arcuate, cornu blunt, ramus obsolete, nodus swollen. Seminal duct long, infundibulum short, denticles on bursa arranged in a clump.

Holotype.— ♂, Cape Henrietta Maria, Lat. 55°, 00′ Long. 82° 15′ Ontario, July 31, 1948 (W. Y. Watson).

Paratypes. — 2 ♀, Same locality, July 6, 1948.

The paratypes are similar to the type with slight variations in the pattern on the elytra. Spot 2 is small but darker in both paratypes while spot 6 is less pigmented and smaller than in the type.

The aedeagus is, in some respects, like that of *H. convergens* Guérin but the sipho and maculation are quite different. The pattern cannot be likened too closely to any of the known species.

Coccinella fulgida n. sp.

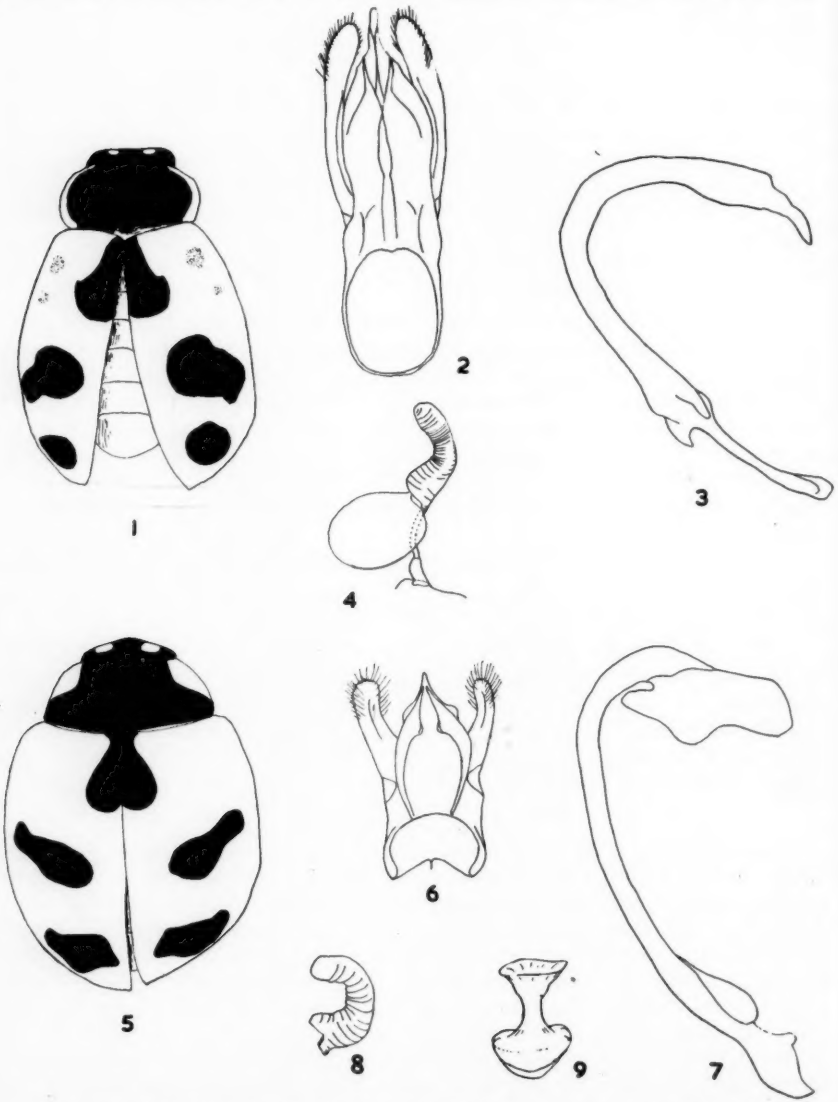
Flattened, somewhat ovoid, not deeply convex. Black with shining, reddish elytra. Head with two large, white spots near eyes, clypeus white. White at anteror angles of pronotum and along lateral margins, pronotal epipleura white anteriorly. Elytra evenly and more coarsely punctate than pronotum, orange-red with small whitish areas near scutellum. Each elytron with one spot and two fasciae (Fig. 5). Scutellar spot (½ + ½) is large and triangular. Spots 2 + 3 form a narrow irregular fascia across the middle of each elytron but not attaining either border, spot 3 is larger and black whereas 2 is small, light in colour and joined to 3 by a still lighter band. Spots 4 + 5 form a thick transverse fascia across each elytron in the apical third. Underside black except for white meso- and metepipleura. Length: 4.5 mm.

1Contribution No. 102, Division of Forest Biology, Science Service, Department of Agriculture, Ottawa, Canada.

2Forest Insect Laboratory, Sault Ste. Marie, Ontario, formerly with Royal Ontario Museum of Zoology and Palaeontology, 1947-48.

Male Genitalia (Fig. 6-7): Siphonal capsule large, truncate; end of sipho with elongate flaps and an inflated terminal portion. Aedeagus slightly shorter than paramera, narrowing abruptly to a very acute point. Basal plate almost as long as wide.

Female Genitalia (Fig. 8-9): Seminal receptacle similar in form to that of *C. nivicola* Menetries but not as sharply arcuate, cornu blunt, ramus truncate. In-



Figs. 1-9. 1-4, *Hippodamia parva* n. sp.: 1, Elytral pattern; 2, Aedeagus and Paramera (♂); 3, Sipho (♂); 4, Seminal Receptacle (♀); 5-9, *Coccinella fulgida* n. sp.: 5, Elytral pattern; 6, Aedeagus and paramera (♀); 7, Sipho (♂); 8, Seminal receptacle (♂); 9, Infundibulum (♀).

fundibulum with a narrow stalk, the opening towards nodus bell-shaped, accessory plate large.

Holotype.— ♀, Cape Henrietta Marie, Lat. 55° 00′ Long. 82° 15′, Ontario, August 15, 1948 (W. Y. Watson).

Paratypes.—1 ♂ same data as Holotype but collected July 25, 1948; also 1 ♀ Langton Bay, N.W.T., Lat. 69° 22′, Long. 125° 11′, Summer, 1911*, (V. Stefansson); 1 ♀ Kater Point, N.W.T., Lat. 67° 42′, Long. 109° 03′, Aug. 24, 1951 (O'Neill)*, 1 ♀ Rampart House, Yukon Territory, Lat. 67° 25′, Long. 140° 53′, (D. H. Nelles); 1 ♀ Reindeer Depot, MacKenzie Delta, Lat. 68° 42′, Long. 134° 03′, June 28, 1948 (J. R. Vockeroth); 4 ♀ Bathurst Inlet, N.W.T., Lat. 66° 50′, Long. 108° 02′, June 11, 19 and July 4, 1951 (C. D. Bird, W. I. Campbell and C. D. Bird).

There is a considerable amount of variation of the elytral pattern in the paratypes. The anterior fascia reduces from a heavy, solid bar to two and finally, a single, small spot, the outer spot disappearing completely. Specimens in which the anterior fascia is greatly reduced have a narrow or divided posterior fascia. Also the scutellar spot may be greatly reduced. Thus the maximum amount of pigmentation consists of a large, triangular scutellar spot and two broad, black fasciae. In contrast, the minimum amount of pigmentation consists of a very narrow scutellar spot, a small remnant of the anterior fascia near the suture and a narrow or divided posterior fascia.

This species is apparently closely related to *C. suturalis* Casey and *C. difficilis* Crotch, the aedeagus being perhaps more suggestive of *suturalis*. The seminal receptacle is much like that of *C. nivicola*.

The specimens of both these species were found crawling about on the sand and could not be associated with any particular plant or plant-feeding insects.

Holotypes and paratypes of each species are to be deposited in the Canadian National Collection, Ottawa. A paratype of *Hippodamia parva* n. sp. will be deposited in the collection of the Royal Ontario Museum of Zoology and Palaeontology.

*These two specimens were identified and recorded by C. W. Leng as *Coccinella nugatoria* Mulsant. Report of the Canadian Arctic Expedition 1913-18, Volume III: Insects, Part E, p. 17, 1919.

Third Annual Meeting of the Entomological Society of Canada

The Entomological Society of Canada held its third annual meeting jointly with the fifty-second annual meeting of the Entomological Society of British Columbia at the Empress Hotel, Victoria, on October 19 to 21. A total of 169 members and friends registered, including 16 visitors from the United States and 33 wives.

In the absence of A. W. Baker because of illness, Rev. O. Fournier, Vice-President, presided. Hon. W. K. Kiernan, Minister of Agriculture of British Columbia, welcomed the two societies.

Rev. O. Fournier congratulated the Entomological Society of Alberta upon its formation in November, 1952.

Invitation papers were presented during two sessions by five prominent biologists: Melville H. Hatch, University of Washington, Seattle; Ian McTaggart Cowan, University of British Columbia, Vancouver; J. G. Rempel, University of Saskatchewan, Saskatoon; B. P. Beirne, Entomology Division, Ottawa; and F. T. Bird, Forest Biology Division, Sault Ste. Marie, Ont. Papers of which titles had been submitted were presented at three sessions, one of these being

devoted to three sections: Agricultural Entomology, Forest Entomology, and General Entomology.

On the evening of October 20th, after a cocktail hour provided by courtesy of Imperial Oil Limited of Canada, about 200 members and friends enjoyed a banquet and entertainment at the Empress Hotel, with G. J. Spencer as master of ceremonies. K. M. King led in a sing-song, assisted by Peter Venables and R. H. Painter. W. A. Ross, Past President of the Entomological Society of Canada, remarked briefly on the high status already enjoyed by the Society and on the impetus the Society had given toward rejuvenating older societies and forming new ones, the nation being served by a commonwealth of one national and seven regional societies. Rev. O. Fournier thanked the Government of British Columbia for interest in the meeting. Guests at the head table included J. Marshall, President, Entomological Society of British Columbia; W. H. Robertson, Deputy Minister of the British Columbia Department of Agriculture; T. Ritcher, Oregon State College, Corvallis; E. J. Newcomer, U.S. Bureau of Entomology and Plant Quarantine, Yakima, Washington; and R. Glen, Chief, Entomology Division, Canada Department of Agriculture, Ottawa. K. M. King, accompanied by Mrs. King, sang two solos: "Clorinda" and "The Vagabond". Dr. Clifford Carl, Director, Provincial Museum of British Columbia, the guest speaker of the evening, presented a coloured film on a bird expedition to one of the Queen Charlotte islands, with commentary. Professor Spencer thanked the various commercial firms that had contributed financially to the success of the meetings. Len Holland (brother of G. P. Holland), Vancouver, gave several concert numbers on the piano-accordion.

On the afternoon of October 19, the ladies enjoyed a tour of the Malahat Drive and the Marine Drive, with tea and crumpets at the Oak Bay Beach Hotel.

At the annual business meeting, the membership fee was increased by $1.00 and the number of pages in the journal was increased by eight per number, effective January 1, 1954. Rev. O. Fournier announced that the Entomological Society of Quebec had received a grant of $300 from the Province of Quebec and had donated it to the Entomological Society of Canada to aid in publishing *The Canadian Entomologist*. It was agreed not to take any action at present on having a mail ballot for the election of officers, or on having an editorial board representing the regional societies. Matters recommended for further attention included the publishing of abstracts of papers, presented at annual meetings, copyrighting *The Canadian Entomologist*, and contracting for reproduction of *The Canadian Entomologist* on microfilm. The interim report of the Treasurer, A. B. Baird, for 1953 showed total receipts of $4,756.15 and total expenditures of $5,125.12 to date and an estimated deficit of $88.97 for the year. There were 330 members paid up out of 451, 304 subscribers paid up out of 305, and 98 exchanges, the mailing list totalling 862.

It was agreed to suggest to the Directors of the Entomological Society of Ontario that the next annual meeting be held jointly with that of their society.

R. H. WIGMORE, *Secretary*.

THE RUNGE PRESS LIMITED, OTTAWA
Mailed: Friday, January 29, 1954